TECHNIQUE OF MARROW NAILING

by

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Foreword to translation of TECHNIQUE OF MARROW NAILING
by
KUENTSCHER - MAATZ

This translation is included here for historic reasons almost as much as for medical reasons. It appears to be the first book about the Marknagel. Although KUENTSCHER is listed as senior author there is good reason to believe that he had little to do with the writing of this book.

MAATZ, who it appears was the author was junior to KUENTSCHER at Kiel. MAATZ is said to have been educated as an engineer before he studied medicine. The multiplicity of ideas and modifications of the basic concept of the nail have been cited as evidence of his engineering background. Certainly in the United States he would be spoken of as a"gadgeteer". Without doubt he is a capable surgeon and qualified to have his opinions.

The personality of two people could not be more opposite in nature. MAATZ the tense, alert extrovert with rapid fire reactions - KUENTSCHER the shy scholarly introvert, self deprecating and carefully thinking things through. One cannot escape the thought that the Surgical Clinic at the University of Kiel must have been an interesting place when these two men were debating a subject.

The publication of this booklet was delayed from 1942 until in 1944 because of a government restriction on paper. In late 1944 an edition of 1000 copies was authorized. Approximately half of these had been distributed at the end of the war. The fate of the other copies and the plates in Leipzig is not known.

There has been no practical way of reproducing the illustrations in the original text. Since many were explained by line drawings these have been traced. Some have been omitted entirely as unnecessary or not suitable for reproduction with the facilities at hand, the important details being lost in the tracing on a mimeograph stencil.

Upon the completion of this task the original text with any reserve copies of the translation will be sent to the Department of the Navy, Bureau of Medicine and Surgery, Publications Division.

HARRY J. ALVIS
Commander MC
U. S. Navy

P R E F A C E

The idea that a fracture may be held in good position until healed by introducing foreign bodies into the marrow cavity is not new. Metal wires and pins and even ivory bolts have been used for this purpose. Without an exposure of the broken ends and the associated danger of infection the introduction of the above mentioned foreign bodies could not be accomplished.

The essential feature of KUENTSCHER's method is the introduction of a foreign body from a place apart from the fracture site. In this it differs essentially from all other methods of operative treatment of compound fractures. Through the use of a specially shaped, very stable, properly constructed, nail-like splint, which forges an elastic union with the inner surface of the marrow cavity, the greatest possible stability of the fracture should be achieved, so that a further support by plaster cast or traction apparatus is not required. By this the disadvantage of a prolonged immobility of the limbs is avoided.

KUENTSCHER has extended the principle of the nailing of the neck of the femur (SMITH-PETERSEN) to the shaft of bones.

That KUENTSCHER's method was at first generally disapproved of when he announced it at the Surgical Congress in Berlin, is understandable. This disapproval only confirms the conscientiousness of the German Surgeons. Above all they were concerned that the introduction of such a large foreign body into the marrow cavity of a bone might be harmful to the patient. I had the same apprehension myself, when KUENTSCHER expounded his idea to me for the first time even after the results of animal experiments were known. This "instinctive" apprehension was not substantiated. Subsequently no undesirable result was observed in humans in the marrow cavity or elsewhere.

The method has now been adopted in numerous clinics and hospitals. It is now being constantly developed. In different places, not only with us at the clinic in Kiel, surgeons try to perfect the construction of the instruments, improve the protection of the doctor from X-rays, and the form of the nail. Besides all these technical matters there is constantly the question of the indications. Gradually it can be ascertained which fractures are suitable, which are less suitable and which are entirely unsuitable for nailing; for which type of fracture in spite of the nail, a cast is still required, which fracture can be subjected to weight-bearing early and which one late.

All these matters are still under investigation. To all surgeons now engaged in the nailing operation or to those who intend to practice it later on this treatise should be a help. It was written to make them acquainted with the present state of our knowledge and besides this to point out the threatening mistakes. I would like to point out here that only the most skilled surgeons acquainted with the treatment of fractures, should be allowed to "nail" and even then only when having a complete armamentarium at their disposal. The nailing operation requires the greatest technical skill.

It is my opinion that KUENTSHCER's method is the greatest advance in the handling of fractures given to the world since the description of the extension nail method of KLAPP. I am quite sure that its use will spread throughout the world.

It is not difficult to bid this book Good-speed, as I am convinced that it will make its own way.

A. W. Fischer, Kiel

P R E F A C E

In December 1942 we had completed for the first time the following description of the marrow nail operation. However, permission to publish the treatise was not given. When these difficulties had been overcome after the lapse of a year, the entire material of illustrations was destroyed during a severe air raid on Leipzig. By my new assignment to sea duty, contact with my publishers and my collaborator has become very difficult. For these reasons the publication of this work was repeatedly delayed. Unfortunately we are also not in a position to print an annex to this treatise with a short summary of the results we have had in the meantime, for, more than 500 nailing operations have been performed since this work was written of which about 400 have been done at the Kiel clinic and the rest in the field or in station hospitals.

In the meantime all of us have learned to resort to makeshift much more. It is not possible at present to get all the instruments described in this book because their construction had to be stopped due to circumstances of the war. Nevertheless it is possible to perform nailing operations with all the responsibility required if the surgeon has at his disposal X-ray apparatus, nails, awls, hammers and block-and-pulley. All the other instruments needed can be replaced and are not absolutely required.

Every beginner is urgently recommended to use at first only the strict indications and to start only with the nailing of the most suitable fractures. In this case he will find full satisfaction with this wonderful method. In the course of time the indications will extend themselves. In every case one must bear in mind the necessity of accomplishing a stable union of the ends of the bones by nailing. If this condition is not fulfilled failures will not be the fault of the method but of the operator.

On board a hospital ship
in the Mediterranean

August 1944 M a a t z

I N D E X

1. INTRODUCTION

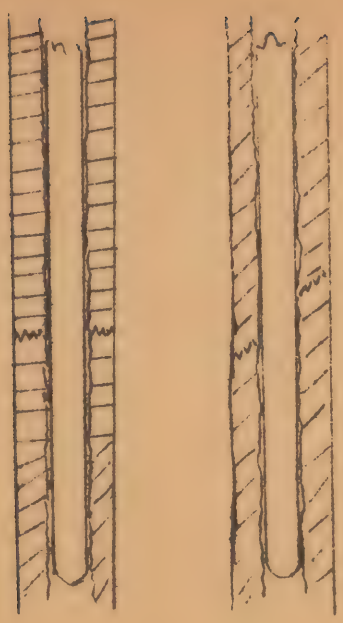
Before the surgeon undertakes his first marrow nail operation he must have a clear understanding of its main principles. Only then will he be in a position to apply the method as widely as the present state of the technique makes it possible. It must not be forgotten that it is a case of true nailing. Just like the carpenter's nail unites two pieces of wood with elastic strength, so the marrow nail is meant to unite the bone ends. The nail should be introduced in such a way by strokes with a hammer into both portions of the broken shaft of the bone that it sticks there and makes it impossible to shift either end of the broken bone shaft. Only by accomplishing this can one speak of an entirely satisfactory marrow nail operation and only then can its great advantages over all other methods be turned to account. A further securing of the fracture by splints, plaster cast or extension will then not be required. The limb may be freely moved, even bear weight. Wasting of the muscles and disturbances of the circulation will not occur, or, if so, only to an unimportant degree. Joint stiffening is not to be feared for the joint is kept at rest. The fracture, placed under favorable mechanical conditions will be bridged over by bone in a very short time, for it is subjected only to pressure while pulling and pushing tensions are avoided.

The nail is held by the friction of the rough inner layer of the cavity of the hollow bone cylinder. Since the inner diameter of the bone varies it is of the utmost importance that the nail should have as much elasticity as possible in the cross section. Therefore the nail is U-shaped in the cross section. After a successful nail operation the friction between the bone and the nail may be so great that the ends of the bone are held together by a force which can resist a pull of several hundred kilograms. But not all broken bones may be treated under equally favorable conditions. The shape of the bone, the shape and location of the fracture and finally the possibilities of introducing the nail into the cylinder of the bone are all of significance. A thorough knowledge of the forces in question in the individual case, both for the indications and for the technique of nailing and particularly for the treatment after the operation is absolutely necessary.

It will not be possible to achieve the aim of the marrow nailing in every case, especially sufficient friction of the nail in both ends of the broken bone. But nevertheless, surgeons may use this method and successfully apply it. It is only important to know how to avoid the weak points of this method.

The mechanical factors are simple and easy to understand.

A bone with only insignificant variations of the diameter of the cavity presents the most favorable conditions possible. (Ill. 1).



Illustr. 1

The location and the shape of the fracture are of no importance if the two fragments are sufficiently long to give the nail a satisfactory hold. In the case of a comminuted fracture, however, the nail alone has to withstand all the forces tending to produce angulation at the fracture site. While in the case of a plain transverse fracture the nail is held by the bone in a firm mechanical system so that the nail alone does not have to withstand the forces tending to produce angulation at the fracture site.

When the friction between the nail and the bone is insufficient, the nail will act as bolt (Ill. 2).

Illustr. 2

Indeed, it prevents a longitudinal bending and lateral displacement, but permits rotation. In this case the shape of the fracture is of decisive importance. A comminuted fracture will shorten and a spiral fracture will be distorted. Even true transverse fractures would not be protected against rotation. On the other hand, oblique fractures usually shorten only as long as there are minor faults of rotation, until finally the nail (bolt) and bone jam. (Ill. 3) In the case of a jagged fracture the

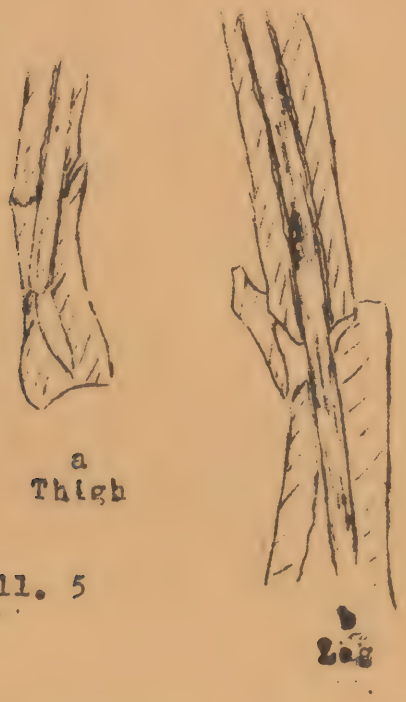
Illustr.3

bone ends can, nevertheless, be united in such a way that the bone ends remain firmly fixed together (so-called Hirth-Teeth). The muscles press the bone ends of the fracture together and in this way rotation is prevented.

The outlook is not so favorable in the case of a bone with considerable variation in the diameter of the marrow cavity. If the fracture lies in the narrowest part of the marrow cavity, a successful nailing can still be achieved owing to the elasticity of the cross section of the nail (Ill. 4). For the distance

Illustr.4

of several centimeters the nail has sufficient friction in the marrow cavity of both fragments. Should this friction be insignificant the nail will act as a bolt and will prevent only a lateral displacement, In the case of a transverse fracture the bone ends, which are in good position and quite secure against lateral displacement will be firmly held together by the muscles and angulation cannot occur, and rotation movements are prevented by the interlocking of the jagged teeth. If a piece of bone is missing at the fracture site the bone ends cannot stand one upon the other longtudinally and there will be a tendency to angulation (Ill. 5). If the fracture does not lie in the narow-

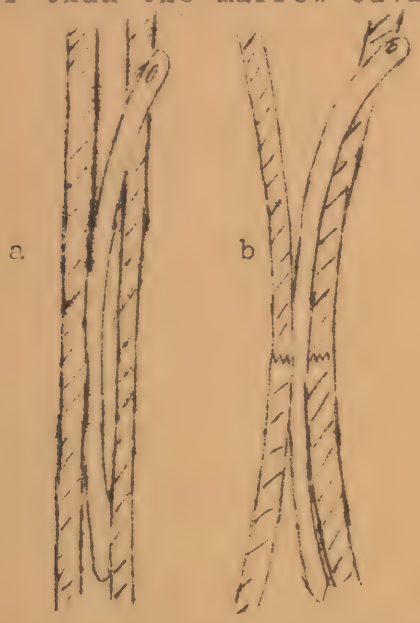


Ill. 5

est part of the marrow cavity the degree of disproportion between the width of the marrow cavity and the thickness of the nail will determine whether the displacement can be overcome by the nail or not. If the broken ends can be displaced laterally by the thickness of the bone cortex we then find the most unfavorable conditions. They are: lateral dislocation, distraction, angulation and rotation i.e., which are all the faulty positions that can be imagined (Ill. 6).

Ill. 6
Unfavorable conditions
for marrow nailing

The situation is more complicated when the nail is introduced into the bone shaft from the side. In the fragment into which the nail has been introduced from the side a rotation is impossible between the nail and the bone shaft but in the other fragment the much desired strong friction uniting nail and bone will generally not be achieved, because the nail must be somewhat smaller than the marrow cavity (Ill. 7). When in this case the



Illustr. 7
a - favorable

b - unfavorable

fracture is situated at the narrower part of a tapering marrow cavity, the difference of the respective calibers, which is necessary for the introduction of the nail, is to no disadvantage. The greater elasticity of the nail, which is necessary for its lateral introduction in these cases is an undesirable feature.

As a further place of friction between the nail and the bone we have the spongiosa of the ends of the bones. While in the majority of cases the stability of the nail in these parts of the bone is irrelevant to the stabilization of a fracture, it is nevertheless of special significance in some cases, and one must understand clearly how much pressure this soft bone tissue can withstand. For example, one may mention the transplantation of the radius to the ulna in the vicinity of the elbow joint. A bony healing was not achieved after five months (Infection preventing the effect of the nail.). The joint was practically immobile. The motion that was possible from 100° to 80°, was not due to the elasticity of the nail, but as the pictures show, the nail had worked a slot in the spongiosa of the bone, in which the end of the nail covered a distance of 12 millimeters (Ill.8).

Illustr. 8

The bone tissue subjected to excessive pressure rhythmically or constantly reacts by absorption at the point of pressure. While in the tubular part, with pressure of the nail from the inside and absorption of the bone at the inner wall, the periosteum prevents a lateral breaking through of the nail by a speedy formation of new bone. Such a reaction is not seen in spongy bones. The nail works itself a slot and finally breaks out of the bone (Ill.9). Therefore a subtrochanteric fracture

Illustr. 9

must not bear weight too early, and the head of the nail must be particularly broad for fractures near the elbow joint, and, for the same reason, it is useless to insert a nail in a fracture of the tibia so far that the point of the nail gets a hold in the distal spongy portion of the bone. This hold is negligible and unreliable.

Our aim and purpose must be the nailing operation. It is not always to be achieved. At least the principle of the bolt should be guaranteed. It still offers great advantages. If a bolting cannot be achieved with certainty the fracture is unsuitable for the new method. Of course, even here there are exceptions to be made and in certain cases one will decide to nail the more readily when the fracture can be brought to a good healing only with difficulty by the methods used previously. As examples one may refer to the comminuted fractures shown in the pictures above, which were nailed with the very best results, although the mechanical conditions were by no means ideal ones (Ill. 10 and 11).

In practice the conditions in some cases may be very complicated. So, for instance, the analysis of the forces which keep a tibia fracture in good position with a spread nail is very difficult and it is impossible to decide whether the security of the fractures is due mostly to the principle of the nail, the bolt, the Hirth teeth or other factors. The only real important thing is that the doctor should attain sufficient skill to recognize as soon as possible to which extent a fracture, treated in this way may be subjected to functional use. For this, it is only possible to give general directions. Personal experience alone ensures a mastery of this subject.

The foregoing statements make it clear that one cannot speak simply of an indication for using the marrow nail. It is necessary to distinguish between "strict" and "extended" indications. In the first group may be included those fractures

Illustr. 10

Illustr. 11

which in the following treatise are considered "particularly suitable", i.e. those fractures which can be treated by the nailing operation much better than by any other method. In the other group are included the fractures considered "suitable" and "less suitable" and at the same time those which do not show all the advantages of the new method after they are nailed.

For the beginner it is advisable to undertake only those cases which fulfil the "strict" indications. With growing experience operations may be performed on cases which are classified under the "extended" indications.

While the nail is in place certain changes occur which must be taken into consideration. The nail may become loose in the bone as early as the first week. The inner wall of the bone is then worn thinner by the pressure of the nail. The consequence is that the friction between the bone and the nail becomes less. As absorption of the bone occurs only at the place of the strongest pressure, a groove in the marrow cavity develops, which permits motion of the fragments in the axis of the bone. Rotational displacement is, however, prevented by the callus which fills the broken ends. Thus there exists the most favorable conditions for the healing of the bone, as the nail acts as a sliding splint and permits only the forces pressing the ends together to act.

It stands to reason that the loosening of the nail after a couple of weeks may be a great disadvantage, according to the form and position of the fracture, therefore it must be considered accordingly.

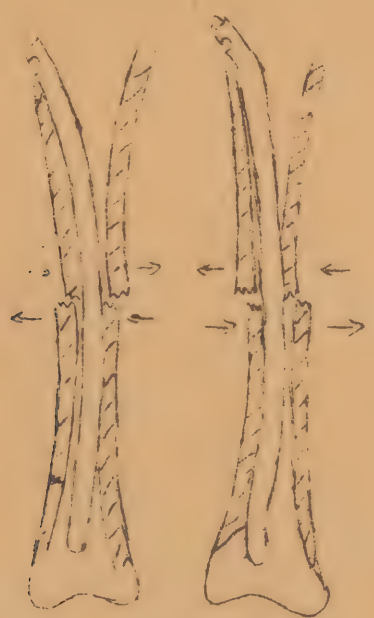
A blocking effect of the nail is irrelevant if the nail provides sufficient stability and has a sufficient hold for the fragments. The bone gap will be bridged over in a surprisingly short time.

If a sufficient stability of the nail or sufficient friction between the nail and the bone does not exist the blocking effect of the nail may result in a delayed healing of the fracture.

The point of the nail, acting as a bolt, produces a constantly widening slot in the short fragment, and thus a lateral piercing by the nail of the periosteal callus which is under pressure is prevented. The fragments are not fixed firmly. How strong the blocking effect of the nail may be is proved by the fact that nails, under the above mentioned conditions, frequently begin to move and thus work their way out of the bone.

The moving of the nail is always a proof of an insufficient stabilization of the fracture by the nail. A fracture is never firm as long as it allows the nail to work itself out.

Even an apparantly well-fixed nail in a fracture favorable for nailing may lead to disturbances of the healing process and finally to considerable delay in the formation of callus, if even a single mistake is made. If in a smooth transverse fracture in the middle of the leg, for instance, a nail is introduced that is too thin, this may permit shearing forces to act at the fracture site, which does not permit a bony healing at all or only a very slow healing. The reason is that gradually the nail will bend a little, and at the same time the upper part of the fracture will move forward and the lower part backward as much as the difference between the diameter of the nail and the marrow cavity permits. When the weight is taken off the elastic forces of the nail will push the bone ends back to their former position. Even if the distance is only $\frac{1}{2}$ or 1 millimeter this displacement will be enough to delay a bony healing or even to make it impossible (Ill. 12).



Illustr. 12

Here are some other brief comments important for considerations in connection with the nailing.

As the fracture is nailed from a considerable distance and the operation wound will be only some centimeters long at the most the danger of an infection will be very slight.

The nailing is not a serious operation which might endanger the life of the patient. Just like other operations, the nailing too must, of course, not be done in shock.

An insignificant fat embolism is to be expected (MAATZ). Clinically it does not appear but even this slight additional hazard must not be added to cases already in a precarious state.

A good formation of callus may be expected only if a stabile osteosynthesis has been attained. A very abundant formation of callus may be caused by the issue of the marrow at the fracture site (KUENTSCHER). Nothing has been said yet about the fixing of the fracture. The chemical stimulation by the metal of the nail may cause a far reaching disorganization in the nailed bone and along with this an abundant periosteal formation of callus. This occurrence is to be considered as undesirable. The fixing of the fracture may even be prevented (MAATZ). Therefore the nail should be made of corrosion-proof metal.

The most careful consideration of the following technical directions is urgently recommended. The nailing operation is a kind of operation which owing to its technical character is not in the line of every surgeon. There are easy as well as difficult cases of nailing and one should always be prepared for the latter. Never make the mistake of considering a case of a nailing operation as"finished and done with". For a successful nailing operation always requires a careful clinical and ambulatory observation to meet every complication which may occur in the course of time. Then only can the new method show how vastly superior it is in comparison with the nitherto used methods.

2. TOOLS

NAILS

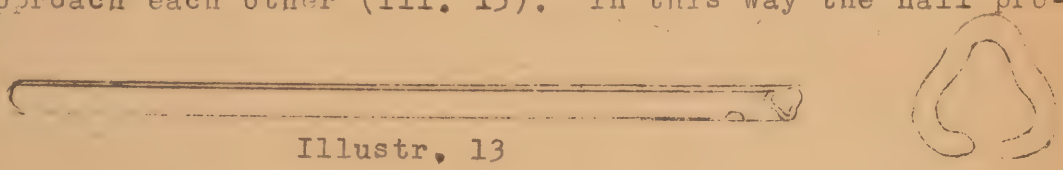
The above described mechanical conditions of the marrow nailing operation make it clear that the marrow nails now available do not make it possible to obtain a stabile osteosynthesis in every case. The nail lies close to the inner wall of the bone shaft not only at the fracture site but also beyond it as far as possible. To attain this end the nail must have great elasticity in the cross section because the diameter of the marrow cavity varies considerably. This required elasticity in the cross section is much greater than that attainable by the most favorable cross-section design of the nail if the thickness of the sheet metal is adequate. Therefore nails must be constructed which can be spread at the desired spots and, further, which make it possible to furnish the nails with cams at the required spots. These cams are meant to enter into the inner wall of the bone in order to prevent a rotation of the fragments. When constructing nails of new shapes one must consider that any complicated construction is of no value and must therefore be rejected. One must never forget that the nail must be strong enough to bear heavy mechanical pressure, breaking of a nail should be an extremely rare occurrence and that the nailing of the marrow should not be reserved for some few highly skilled specialists, but should be available for the use of a majority of surgeons.

The circumstances of war with the scarcity of labor and the difficulties of getting the necessary material have of course delayed any further development so that we have to reckon only with the instruments presently at our disposal and so have to get along with some disadvantages. Unquestionably we are at the beginning of a new development. Under the prevailing conditions it

will be neither possible nor advisable that every hospital or clinic adopting the method of the marrow nail operation will have supply of complete sets of nails. The most commonly used sizes must suffice for the present and the nails needed for special cases must be ordered by cable. The postponement of the operation caused by this circumstance is only a matter of a short time and there is no question that it is justifiable.

Nails for the thigh.

The cross section is approximately V-shaped. The thickness of the metal sheet, required for the stability of the nail, is somewhat less at its back so that the two sides of the nail may easily approach each other (Ill. 13). In this way the nail pro-



Illustr. 13

vided for particularly wide marrow cavities (to 16 millimeters) may be constructed of a thinner metal. Accordingly the elasticity of the cross section is increased considerably.

Customary sizes are:

A d u l t s : Lengths: 30, 34, 36, 38, 40 and 42 centimeters. Cross Section: 8, 9 and 10 millimeters (special sizes of 11 - 16 centimeters are often used).

C h i l d r e n : Lengths: 24 - 32 centimeters (at intervals of 2 centimeters). Cross Section: 6 and 7 millimeters.

For the subtrochanteric fracture a conical nail is provided corresponding to the form of the marrow cavity to prevent a lateral displacement with transverse fractures, and especially to prevent an inevitable shortening when a nail that is too thin is used (Ill. 14).

Illustr. 14

If a bone is to be nailed in which callus is to be expected in the marrow cavity (f.i. refracture or a delayed formation of callus) and if one does not wish to lay open the bone, one may make use of a nail which has serrated teeth at its point (Ill.15).

Illustr. 15

Nail with serrated teeth

By means of those teeth the nail can work a bed into the bone for itself. With them the introduction of the nail may be impossible. (Editors Note: In such a case, where callus fills the marrow cavity, it is customary to perform the "open" nailing, exposing the fracture site and reopening the marrow cavity with a drill or an awl).

The Y-nail is a conical thigh marrow nail of 32 millimeters length and a V-shaped cross section of 10 millimeters. A nail which in its cross section is shaped like a T and stands at an angle of 45 degrees to the axis of the long nail is introduced through a slot in the marrow nail into the head and the neck of the femur. The middle of this slot is about 8 centimeters beneath the end of the nail head. The cross nail (I-shaped) is 11,5 centimeters long and its head stands out of the nail about 2 centimeters in order to find sufficient hold in the cortical's drill hole (Ill. 16).

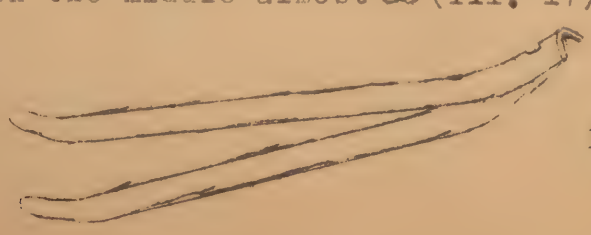
Illustr. 16

For the pertochanteric fractures of groups III and V the marrow nail must be constructed according to the measurements of the bone because it must lie in the thigh bone so snug that it cannot turn round.

The directing apparatus for the Y-nail, which permits a percutaneous introduction of this nail, will be described in chapter 19.

Nails for the Leg.

Nails for the leg are double nails. Their cross section is U-shaped. They are curved, the radius being shorter at the ends, and in the middle almost ∞ (Ill. 17)

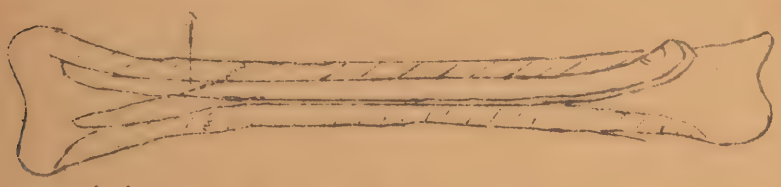


Illustr. 17

A d u l t s : Lengths: 24 - 39 centimeters at intervals of 1½ centimeter. Greatest diameter 8 and 9 millimeters.

C h i l d r e n : Lengths: 15 - 27 centimeters at intervals of 1½ centimeters. Greatest diameter 7 millimeters.

With spread nails, two different shapes have been used with success: the double nail with an inclined plane and the turn-spread nail. The former one is a regular double nail for the leg which can be spread in its distal part by an inclined plane and the turn-spread nail. The former one is a regular double nail for the leg which can be spread in its distal part by an inclined plane attached to the outer nail (Ill. 18). The inclined

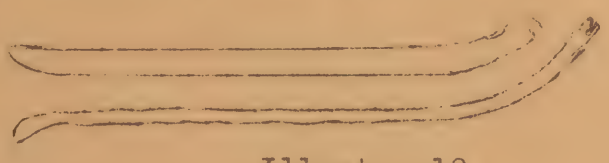


Illustr. 18

plane (a) and the back wall of the bone tube (b) form the lateral supports which bend off the inner nail backwards. The location of the inclined plane is of the utmost importance for the effectiveness of the nail and must therefore be determined very accurately after studying the X-ray. A spread nail having the width of 8 millimeters and the length of 32 centimeters the inclined plane of which is 6 centimeters from the nail tip, is described as U-Schenkel-Spreiz 32/6cm./8mm.

The double nail with an inclined plane is a very stabile system. For that reason it must always be used in all those fractures located distally to the narrowest part of the marrow cavity, the fracture lines of which are more oblique or, in those which have a tendency to angulation because of a breaking off of bone particles especially at the front edge.

The turn-spread nail also consists of two nails. The outer nail corresponds to a normal nail. The inner nail has a round cross section and is in its longitudinal profile S-shaped (Ill. 19). The lower part of the nail is introduced in such a way that its concave part points to the front. After that the nail is to be turned by 180 degrees by means of a screwdriver. The outer nail is driven in while the inner nail is secured by a crosspin or a supporting wire against any further penetration.



Illustr. 19

The turn-spread nail is suitable only for transverse fractures or short oblique fractures the fragments of which stand one upon the other as soon as they are bolted. This nail can act only as a bolt, because the inner nail lies comparatively loose in the marrow cavity and because of its greater elasticity it does not offer sufficient resistance to a stronger lateral pressure(Ill. 20).

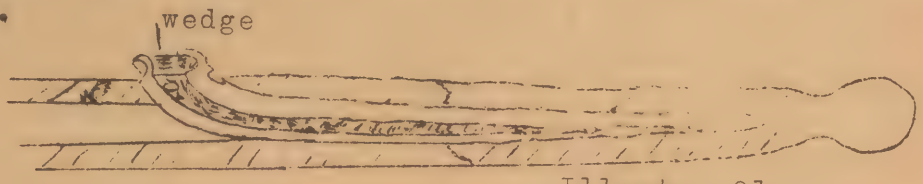
Nails for the Arm above the Elbow.

They correspond to the leg nails for children.

Illustr. 20

Wedge for the Arm above the Elbow and the Leg.

They are intended for fractures proximal to the middle of these bones. For the present they can only be made to measure (Ill. 21).



Illustr. 21

Nails for the Forearm.

The cross section is V-shaped. The nails are furnished straight and are are shaped by the surgeon according to the bone form (Ill. 22).

Illustr. 22

Lengths: 10 - 24 centimeters at intervals of 1 centimeter.

Diameter (for the above noted lengths): 3, 3½ and 4 millimeters.

The special nail for the ulna fracture (near the elbow-joint), has a length of 20 centimeters, its diameter is 6 millimeters in the third near the head end; in the third near the tip, however, it is 3½ millimeters. The corresponding tapering is in the middle third. The last three millimeters of the head end are flat and broad.

The guide rod.

F o r t h e t h i g h : cross section round and solid, for children's thigh nail three-edged. Lengths: 3 and 4½ millimeters. (Ill. 23).

F o r t h e F o r e a r m : Length: 25 centimeters diameter: 2 - 2½ centimeter.

Ill. 23

The Awl.

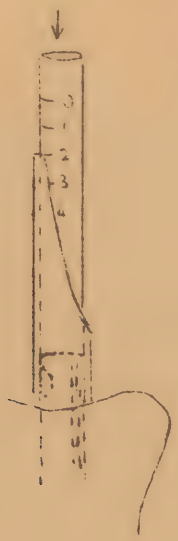
The bayonet-shaped awl, the tip of which is square-edged, has proved most suitable for the leg, (Ill. 24).

Illustr. 24

Nail sets.

The nail set for the thigh nail is simply a piece of a thigh nail 20 centimeters long. It is put upon the thigh nail when the nail head end has not yet reached the head end of the guide rod and the rod must not yet be removed.

Nail set II for the thigh nail fulfils the requirement that the nail should project out of the great trochanter. The hollow case slipped over the nail is pressed firmly upon the bone. The bolt is then pressed firmly upon the nail head. The bolt which can be moved in the hollow is graduated at its upper part. The number of centimeters the nail stands out at the time can be read at the top. The hollow case is wide open on one side so that it and the bolt can be firmly gripped in order to prevent the hollow case from slipping back at the moment of the stroke (Ill. 25).



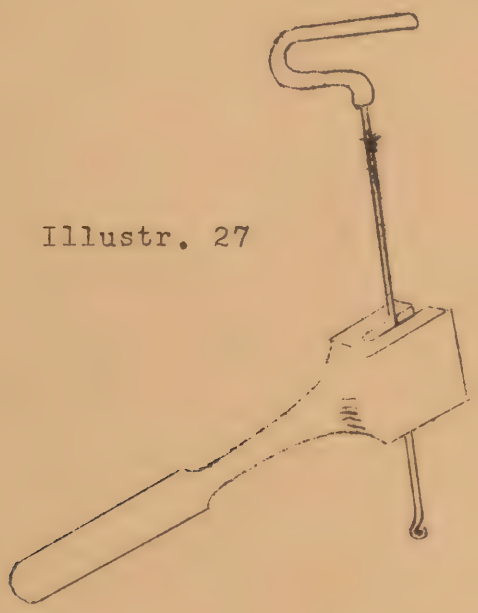
Il ustr. 25

The nail set for the plain leg double nail facilitates the driving in of the nail because it renders it pos ible to direct the stroke according to the chief dir ction of the principal axis of the nail. By this a strong springing of the nail is prevented (Ill. 26).

Illustr. 26

A metal bolt of 10 centimeter in length with a diameter of 1,5 centimeter serves as a simple nail set for the last strokes upon the leg nail the forearm nail and the upper arm nail.

The split hammer is the best tool for striking out even firmly fixed nails. The force of the stroke is transmitted to the nail directly and in a straight direction. For the big nails the long hooks are used, for the small nails the shorter ones (Ill. 27).



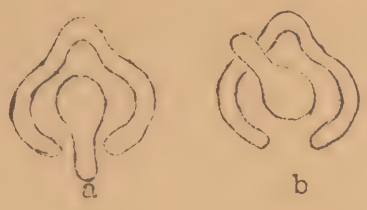
Illustr. 27

Pull and stroke are combined in the tool constructed by KUFNTSCHER. To prevent any chipping of the bone at the point of contact a separating disk acting on a ball and socket is used. The threaded spindle with a spring acts as a "relay" which has to be reset after a couple of hammer strokes. The inset must be inserted when the nail stands out of the bone for some distance.

For removing the second piece of a straight nail, broken in the marrow cavity (thigh, forearm) the same hammer is used together with a removal hook of a length of 75 centimeters, the so-called nail catcher (Ill. 28). It must be introduced into the marrow cavity at the site of the nail insertion. After

Illustr. 28

having reached the broken nail it must be pushed into its cavity carefully so that the hook finds sufficient space in the open side of the nail. When the hook comes out at the end of the nail it must be turned by 120 degrees (not by 180 degrees, see Ill. 29) and the nail must then be extracted or struck out. For the

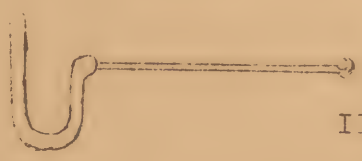


a- during insertion
b- extracting of the nail

Illustr. 29

ulna nail the nail catcher is slightly bent and elastic, and is introduced by the hook closed side of the nail. The hook catches the nail tip behind at the moment when it leaves the nail. A rotation is not necessary in this case.

The extraction hook is suitable for nails which can be removed easily (upper arm and forearm(Ill.30).



Illustr. 30

The nail bender (Ill. 31) permits the necessary shaping of the nail (with the exception of the thigh nail) without damaging the polished nail surface an event which may happen very easily when using pincers.

Illustr. 31

The comparison-scale (Ill. 32) serves to ascertain the diameter of the marrow cavity. It is attached to a belt with a balancing weight and is put upon the limb before the first X-ray in all cases of fractures which seem to be suitable for nailing in such a way that the scale is on a level with the middle of the bone. The central beam of X-rays has to be halfway between the bone and the scale. Each grade corresponds to 2 millimeters.

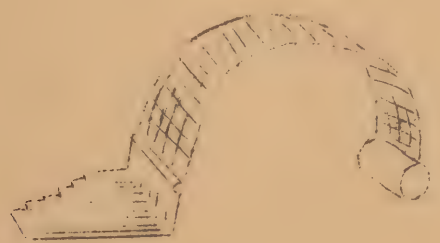


Illustration 32

The isolating wire frame for the thigh and the leg serves to facilitate the asepsis. It erects a "wall" 4 centimeters high between the aseptic and septic parts and leaves upen only a small area of the skin for the small operation wound.

The repositioning apparatus (MAATZ) is used for the repositioning of the fracture fragments . Practically it is a lengthening of the arms of the operating surgeon. The apparatus stands on the floor without any connection with the extension

table. Since the forces acting upon the extremity nearly neutralize each other it is not necessary to fasten it to the floor. The floor friction is sufficient. The rough adjustment brings the grasping arms to the desired level. The movements of the lateral levers are transmitted by a universal joint to a gear mechanism in such a way that strength is saved though the extent of motion is less. By means of this apparatus interlocked fragments may be freed, moved around each other and put together in the most favorable position for the fracture as required for long oblique fractures and spiral fractures. The crepitation of the bones touching each other is transmitted so well by the instrument that it is imparted to the hand of the manipulator. Each plane can be fixed by an adjusting screw. This advantage is of the utmost importance especially with transverse and over-extended oblique fractures.

The semicircular pads can be changed according to the thickness of the extremity. The leather strap which has two big holes must be pulled over the ends of the pads in such a way that the leather strap and the pads form a complete ring and that this ring is formed at any diameter half by the pad and half by the strap. In this way a firm grasp of the extremities is achieved, The straps must be tightened very firmly because any slackening will diminish the effect of the manipulations too much. The pads are mounted on a joint that may be turned so that they stand nearly vertically to the axis of the leg or the arm. Thus the fracture site remains uncovered for the X-ray.

Fractures that can be reduced only by using very strong force (i.e. supracondylar femur fractures) cannot be replaced in the normal position with this apparatus. In that case it will be better to use a regular block-and-tackle that can be attached to hooks in the ceiling and the wall. Other adjusting devices have been constructed by HERZOG, LINSENMEYER, ZOTTL and WITTMOSER.

3. THE INDICATION AND DETAILED STATEMENTS ABOUT THE AFTER-TREATMENT.

The following possibilities for the use of the marrow nail are given. The indications may be:

1. Every fracture suitable for the nailing operation may be treated with the marrow nail, or

2. The procedure is reserved for those patients who are particularly endangered by confinement to bed, plaster cast or extension treatment, or

3. those fractures which present great difficulties in treatment may be nailed, such as plain transverse fractures which often heal in lateral displacement and which show the tendency to refracture, or

4. the nailing treatment may be used for those fractures that may be replaced in the normal position but the fragments of which can by no other method be kept in the proper position and which slip again and again. These fractures would otherwise require an open fracture treatment. Here the indications for marrow nailing are the possibility of avoiding the opening of the fracture with all its dangers and disadvantages. These cases are not unusual.

5. A special indication is given for spontaneous fractures

in the cases of tumor metastasis. Strange to say the majority of these fractures are subtrochanteric. The patients concerned must be treated with plaster cast and confinement to bed for life because these fractures do not tend to heal, not even by frequent irridiation or other forms of treatment. With the marrow nail treatment these patients can at least stay in bed without pain, in some cases they may even become ambulatory although there is no hope for a bony healing of the fracture.

In this way every surgeon who wishes to become familiar with the use of the new method has a good chance of starting with the strictest indication possible and then extending the indications constantly with growing experience. Since its introduction the new method has proved its value to such an extent that the disposition to treat every suitable fracture with the marrow nail can be considered as justified. The question "Which fracture cannot be cured conservativ-ly?" considered under the influence of the marrow nailing leads to the further question "Which fractures cannot be nailed?".

The indication is different with children. Here, the fractures will heal very quickly, stiffening of the joints need not be feared, danger by cast or confinement to bed is of no serious importance, minor defects in the position are compensated for later on to an astonishing extent. The indications may be the more strict the younger the little patient is. With the baby there is only the smooth transverse fracture of the thigh bone which does not regain the normal position in a suspended position. But, the older the child is the easier it will be to decide for nailing a fracture in order to shorten the time of confinement to bed, the stay in the hospital and the duration of the disease. None the less the indication will always be more strict than with adults for reasons mentioned above. Technically it is quite possible to nail even babies.

The following statements are based on the proposal to nail every fracture suitable for the marrow nail.

The question whether a fracture is suitable for the marrow nail operation or not depends on the shape of the bone tube, and the shape of the fracture. The situation is somewhat complicated in many cases and the gradations of suitability vary so that it seems to be advisable to distinguish the following groups:

"very suitable"
"suitable"
"less suitable"
and "unsuitable".

It must be emphasized that these general directions are given with respect to the present stage of the marrow nail technique. It may be hoped and is to be expected that with the further development of this method the general conditions will improve greatly. At present it is advisable to apply a strict standard because it concerns a treatment which is meant to replace other well-tried methods.

Totally excluded are all fractures involving joints because the nail may separate fragments which still are in fair position, while the nail may not find sufficient hold and the joints are endangered by the introduction of the nail. An exception is the T-shaped fracture in the femur section of the knee-joint. It will be dealt with separately later on.

The suitability of a fracture for the marrow nail operation depends not only on the extent to which a nail may be fixed securely in the bone ends. Other considerations may be of great importance as for example, with supracondylar fracture. Here the conditions for an ideal nailing operation are extremely poor. The nail guts out of the wide marrow cavity of the distal fragment as a bolt because its diameter is much too small. Additional support by aplaster cast is required. But, nevertheless there is no better method of treatment, because the fragments cannot be fixed together so well by any other method.

Therefore it is necessary to discuss the indication in every particular case with regard to the limbs and types of fractures. The circumstances, on which the suitability of a fracture for the marrow nail operation depends determine also the method of the after treatment. Therefore we must discuss the essential facts together with the indications in order to prevent any unnecessary repetition. Nevertheless, the general directions will be dealt with in a special chapter of this book.

A. THE THIGH.

The femur of the adult resembles most a bone tube which has the same diameter throughout. A straight nail can be introduced from the trochanter. That means that the conditions are very favorable.

a) Pertrochanteric fracture.

"unsuitable"

because the head end of the nail does not find sufficient hold in the upper part of the trochanter. Suitable for treatment with the Y-shaped nail (Ill. 16).

Illustr. 33

b) Subtrochanteric fracture

"very suitable"

Secure against bending of the axis. Slight lateral displacement can be prevented by a conic nail.

Illustr. 34

Secure against rotation because the nail finds a firm hold in the spongiosa in the proximal sector because of its V-shape, while in the distal fragment conditions are favorable for sufficient friction.

Additional support not required. Weight bearing not advisable until the lapse of three weeks. With a premature weight bearing the nail might work itself out laterally through the spongiosa of the proximal fragment.

c) Transverse and oblique fractures.

The short fragment of which has a marrow cavity suitable for nailing and which is at least 8 centimeters long.

"very suitable"

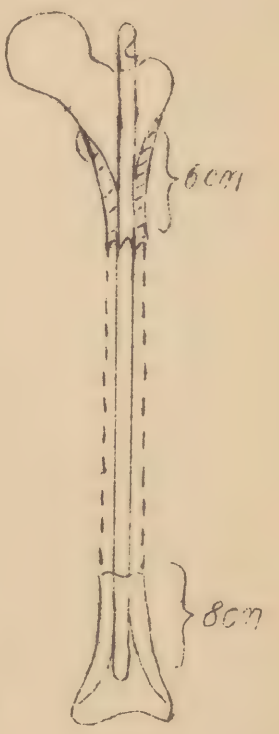
Secure against angulation lateral displacement and shortening. The danger of rotation depends on the amount of friction between the nail and the bone and is less with a jagged fracture or with an oblique fracture and which is greater with a smooth transverse

fracture. Additional support is required only if rotation occurs. Weight bearing is possible immediately. (Ill. 35)

d) Spiral fractures.

"suitable"

Secure against bending of the axis and lateral displacement. Shortening occurs simultaneously with rotation faults because the smooth fracture ends will slide past each other with weight bearing. (Ill. 36)



Illustr. 35

Additional support is required only when rotation occurs.

Weight bearing not before the lapse of three weeks.

Illustr. 36

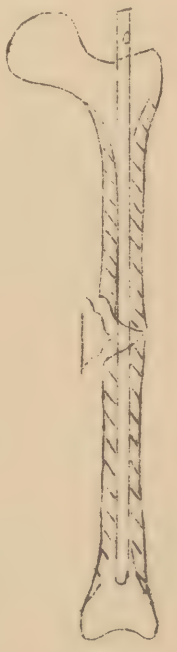
e) Comminuted fractures

1. The large fragments are intact in their full length in one area.

"very suitable"

Lateral displacement is impossible. Security against angulation depends solely on the stability of the nail. Shortening is impossible because the large fragments are intact in their full length in one area. Rotation quite possible because it is prevented only by the friction between the nail and the bone, as the fracture is not jagged.

Additional support necessary only in case of danger of rotation. Weight bearing possible immediately. (Ill. 37)


Illustr. 37

2. Intact bone tube in the third fragment.


Illustr.38

"very suitable",

conditions as under c.(Ill.38)

3. Comminuted compound fracture.

"suitable"

Secure against lateral displacement. Protected against angulation solely by the stability of the nail.

Danger of shortening and rotation is very great because it is prevented only by the friction between bone and nail. (See also: gunshot fractures)

Additional support by wire extension probably required. Weight bearing after a sufficient formation of callus. (Ill. 39)

Illustr. 39

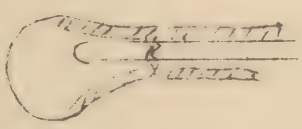
f) Supracondylar fracture

"very suitable"

because it is difficult to treat by other methods.

The nail prevents the small fragment from slipping out of position. Small displacements are possible in every gradation, because the nail lies as a bolt in the marrow cavity which is too wide.

Illustr. 40



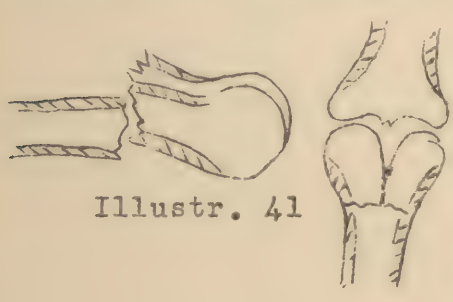
A reduction as ideal as possible should be striven for.

Additional support (high plaster cast for the leg, sometimes only Braun's splint) always required for four weeks. Weight bearing possible after six weeks.

g) Supracondylar fracture with condylar separation.

(Y-fracture)

"Unsuitable" for the simple marrow nail. As it is very difficult to treat such a fracture by the methods hitherto customary and as success is very uncertain, the treatment with a special nail is recommended.



Illustr. 41

The younger the individual concerned the less favorable will be the conditions for the nailing of the thigh, since the marrow cavity shows a fairly marked narrowing in the middle of the shaft during the years of growth. This fact has to be taken into consideration as regards the indications and the after treatment. The fractures suitable for the marrow nail operation generally are limited to the middle third of the bone. This fact is not of so much importance in children because most fractures are usually situated in that third.

B. THE LEG

In the leg the situation is comparatively much more unfavorable than with the thigh, even with adults. The marrow cavity shows a considerable waist-like tapering in the middle. The nail must be somewhat bent because it must be introduced laterally. At the same time the nail has to be flexible and elastic to such a degree that it may prove a great disadvantage for the stabilizing of the fracture. As the nail must be introduced laterally in front, its curve must be concave shaped to the front. Leg fractures lying in the middle third of the shaft quite often will show a tendency to recurvation. The nail which must have a similar slight curve will often not be strong enough to counteract the forces of recurvation sufficiently. Therefore this most

Page 28 missing

The fragments are protected only against rotation and not against the other possible kinds of displacement. During the insertion the nail tends to push the lower fragment backwards. It is very difficult to prevent this dislocation and in many cases it will be impossible to counteract it even with an exceptionally wide curved radius in the upper section of the nail. Even a successful repositioning of the nail will not protect the bone cylinders from sliding off again. Even if the fragments do not slide off a stabilization by the flexible nail will always be too slight because the latter lies almost "loose" in the marrow cavity so that it cannot neutralize the disadvantageous forces existing in that part of the bone.

The forces disadvantageous to bony healing, are very great. This is proved by the fact that compound fractures near that place are often observed. This fracture is suitable for a nailing operation by the use of a wedge which must be driven in between the inner and the outer nail. By this a very good "bolting" is achieved so that the fragments stand firmly together.

b) <u>The difference between the diameter of the marrow cavity and the thickness of the nail is smaller than the thickness of the bone mantle.</u>

<u>a) Transverse fractures (in the upper third).</u>

Illustr. 44

(m - n < k)

"less suitable"

A sliding off of the fragments is impossible (Ill. 44). It is protected against rotation in the upper fragment by a lateral nail bed, in the lower fragment by the friction between the bone and the nail, and in addition by any bone"teeth".

The reason for its being "less suitable" is the fact that the nail, owing to the insufficient friction between it and the bone, does not stabilize the fracture sufficiently at the fracture site to guarantee a quick bony healing without additional fixation.

Plaster cast is required.

Weight bearing with the plaster cast is immediately possible.

A safe nailing may be achieved by utilizing a wedge, driven in between the inner and the outer nail.

<u>b) Oblique fractures (in the upper third)</u>

(m-n<k)

"less suitable"

Ill.45

A slight lateral displacement and shortening to a small extent, will always occur. (Ill. 45)

It is well protected against all further displacement because of the great friction between the bone and the nail (at x). By this a sufficient stabilization at the fracture site is achieved.

Additional support not required.

Getting up after three weeks possible.

It is recommended to use a wedge.

e) Spiral fractures (in the upper third)

(m-n<k)

"less suitable"

Illustr. 46

Here we have the same conditions as with oblique fractures (2b), Strong torsion forces are added which cannot be completely neutralized by the nail, because the distance between the upper nail bed and the marrow cavity wall is too large in the distal fragment.

Additional plaster cast for the leg is required. Getting up with the cast is not advisable until the lapse of three weeks. Use of a wedge is recommended.

d) Comminuted fractures (in the upper third)

(m-n.k)

"unsuitable"

Illustr. 47

By the breaking out of larger or smaller particles of bone, the most essential factor which made a nailing operation effective in the upper third no longer exists, i.e., the standing of the fragments one upon the other. By this the fracture slides off or, if this does not occur, the result will be angulation to the side, where a piece of the bone has broken out, caused by the missing support of the fragments on the side. The stability of the nail which is not supported by the bone is insufficient(Ill. 47).

e) Comminuted compound fractures

(in the upper third)

"unsuitable"

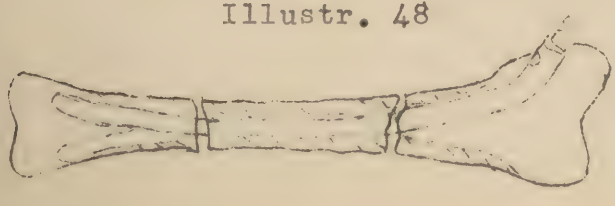
In this case a considerable aggravation of the unfavorable conditions prevailing with the compound fractures will occur.

2. Fractures in the middle third.

Since the diameter of the marrow cavity is either quite the same or about the same as the thickness of the nail, all these fractures are suitable for a marrow nail operation. Thanks to the elasticity of its cross section the nail will fit tightly into the marrow cavities of both fragments and sufficient friction will be achieved.

a) Transverse fractures (in the middle third)

Illustr. 48



"very suitable"

Lateral displacement and shortening are impossible. Bending of the axis will be unlikely, owing to the stability of the nail, above all owing to the standing one upon the other of the bone tubes.

Page 31 missing

nail does not suffice to prevent angulation with absolute certainty. Particularly unfavorable is the situation in case of the breaking out of a triangle in front, since the curving of the nail will often result in a displacement in the nature of a recurvation.

In using the simple double nail an additional leg cast is nearly always required.

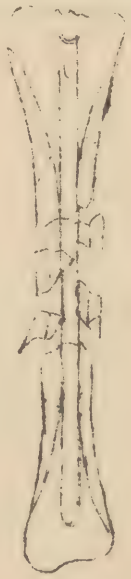
Weight bearing (during wearing of the cast) according to the shape of the fracture but not before the lapse of three weeks. A better stabilization will be achieved by the spread nail with an inclined plane so that additional bandages are not required.

Illustr. 52

In case of a double fracture of the tibia (Ill. 52), i.e. in the case of the breaking out of a fairly long bone tube, marrow nailing is absolutely indicated. The central fragment is strung upon the nail. If the two fragments are in a place favorable for nailing, the situation is very favorable. If, however, one of the fractures is situated in an unfavorable place this disadvantage must be accepted. At least one of the fractures is then kept in a favorable position. An additional plaster cast protects the other fracture against excessive displacement, so that the advantages of the nailing are still paramount. Both the wedge and spread nail are suitable, according to the shape and the site of the fracture, to stabilize these fractures without an additional plaster .

e) Comminuted compound fractures (in the central third)

"less suitable"



Illustr. 53

The fracture can be stabilized sufficiently by the mere solidity of the nail.

Lateral displacement is impossible. All other possibilities of displacement must be eliminated by the application of a plaster cast (leg and thigh).

Weight bearing not advisable before a sufficient formation of callus has taken place. Otherwise the fracture might be shortened.

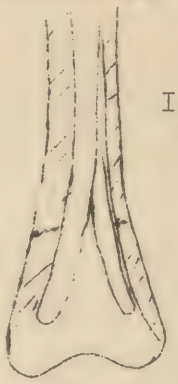
In any case the application of a spread nail with an inclined plane is indicated.

3. Fractures in the lower third.

Here, again the suitability of the fracture for marrow nailing depends decisively on the amount of the disproportion between the diameter of the marrow cavity and the thickness of the nail. That is why the use of the spread nail in such cases plays a very important part. The double nail, forking in its lower part, may have a much greater diameter than the narrowest part of the marrow cavity about the middle (center) of the bone shaft. While the simple double nail may be used for fixing toothed transverse fractures above the point where the above mentioned difference is less than the thickness of the bone cortex, the spread nail can be used with good result in many more cases. Therefore, the

use of the spread nail is presupposed in discussing fractures in the lower third of the tibia.

a) Transverse fractures (in the lower third)



Ill. 54

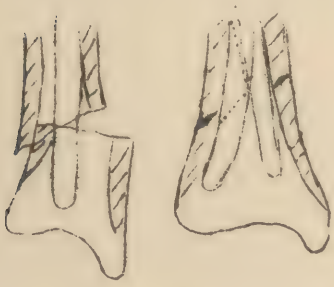
Shortening not possible. Protected against lateral displacement by the nail, against rotation by teeth and occasionally also by the nail, against angulation by the pressing together of the fragments by the muscles, occasionally also by the nail.

Additional support not required.

Getting up after the lapse of a fortnight. Turn-spread nail is recommended.

b) Oblique fractures (in the lower third)

Illustr. 55



I. The fracture plane leans obliquely downwards towards the inner or outer part.

a) Difference between the diameter of the marrow cavity and the thickness of the nail greater than the thickness of the bone cortex. "Unsuitable" for the simpel double nail because displacements of all types are possible. The spread nail with inclined plane protects the fragments sufficiently if the spread plane comes to lie to the frontal plane (see insertion of the nail).

b) The difference between the diameter of the marrow cavity and the thickness of the nail is less than the thickness of the bone cortex.

Illustr. 56

"Suitable". After the only possible displacement has taken place, accompanied by slight dislocation sidewards resulting in a shortening, a jamming of the nail and the fragments takes place. A further lateral displacement is prevented by the nail, a bending of the axis by the bone tubes standing one upon the other and rotation by Hirth-teeth and all the muscles, which counteract a lengthening of the bone.

Plaster cast not required.

Getting up after the lapse of three weeks.

Spread nail with inclined plane recommended.

II. The fracture plane leans obliquely downwards to the front or to the back.

Without spread nail the same situation prevails as with I. When using this nail (spread nail with inclined plane) the diameter of both nails together will be large enough to prevent a slipping of the fragments. So we find here the same situation as with Ib. The closer the outer nail lies to the bone in front, and the inner nail to the bone behind, the better will a sliding off of the fragments be prevented.

Illus 57

Plaster cast not required.

Weight bearing after the lapse of three weeks.

c) Comminuted fracture and comminuted compound fracture (in the lower third)

"unsuitable"

In either case the nail may perhaps be of a certain value to protect a large fragment against a greater dislocation by protecting it laterally. Generally it will not be possible to ascertain this by the X-ray beforehand, so that a nailing may be performed only at a great risk. On the other hand, the greater part of the comminuted and comminuted compound fractures in the lower third of the tibia show the tendency to involve the joints or affect one or both malleoli. That is the reason why the nailing is contraindicated, in order not to endanger the joint, or becomes unsuitable, because only the malleolar fracture makes the treatment with a plaster cast inevitable.

6. THE UPPER ARM

It is not possible to introduce a straight nail into the upper arm without endangering the shoulder-joint. The lateral introduction of an elastic flexible nail at the upper as well as at the lower end of the marrow cavity, however, is possible. A very broad indication for the nailing results from this. A very short fragment, either near the elbow- or the shoulder-joint, may be laid hold of by the nail and this way a sliding of this fragment may be prevented.

Therefore all fractures which in their shorter fragment have a marrow cavity at least a couple of centimeters long are "very suitable" because there is no better method of protecting the fragments from lateral displacement. The top of the nail may be driven into the spongiosa of the head in order to obtain better protection. In this way a fracture in the surgical neck may be treated by using the marrow nail with the best result.

Site and shape of the fracture are important only as regards the technique of the introduction of the nail (whether from above or below), and at the same time for the after-treatment. Seldom will it be possible to achieve an "ideal" nailing, because of the necessity of inserting the nail laterally. In most cases the thickness of the nail will not be sufficient to achieve a strong friction of the nail and the bone for some distance. (see "general" part. For this reason it will in many cases be possible to decide which kind of after treatment will be required only after the nailing. An important indication of insufficient stabilization of the fracture is a continued tenderness, after the initial wound pain has decreased. Insignificant motion near the fracture site cannot be ascertained by any other method.

Ill. 58

The kind of after-treatment depends also on the age of the patient. The arms of children and juveniles may be treated with the "Desault" bandage without any hesitation. Adults and especially elderly persons must have an abduction splint or an abduction cast because the shoulder may be in danger of becoming stiff.

It is known from experience that the danger of a postoperative torsion of the fracture ends is very small. Therefore a special consideration must

be given to this only in very few cases, Evidently the very flexible shoulder joint constantly yields so much that a displacement by rotation near the fracture site does not occur.

It is hardly possible to mention all the kinds of fractures of the arm above the elbow and it is unnecessary. Therefore, we may select only a few examples. It will not be difficult to apply the principles to other fracture shapes appropriately.

For the nailing technique it has been proved practically to divide the bone into four sections, the first of which lies near the elbow joint.

a) Transverse fracture in the third section

"very suitable"

Nailing from below, to give the nail a sufficient hold in the short fragment. Most favorable conditions because the nail finds sufficient friction at many spots of the marrow cavity though its thickness is necessarily insufficient. Thus the fracture is sufficiently stabilized. Bending of the axis is possible only to a negligible extent.

Ill. 59

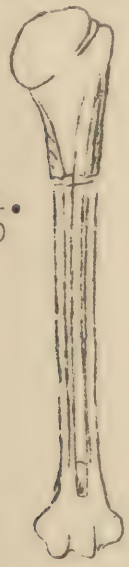
Additional support is not required.

Exercises are possible immediately.

b) Transverse fracture in the first section.

"very suitable"

Nailing from below, since in this way only the exposure of the fracture can be avoided, while the top of the nail will find an additional hold in the spongiosa.



Ill. 60

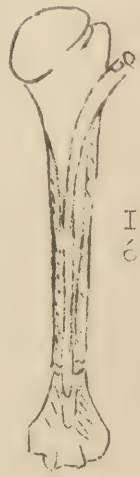
Additional support is seldom required.

Exercises are possible immediately.

c) Transverse fracture in the fourth section.

"very suitable"

Nailing from above, because the distal fragment ment is too short, It is well protected against lateral displacement and probably also against rotation. The thickness of the nail must be much smaller than the diameter of the marrow cavity. The nail must not reach the distal end of the marrow cavity, in order to prevent a firm jamming. The nail is meant to act merely as a pin preventing a lateral displacement.



Ill 61

Abduction cast for three weeks. After that, the cast must be cut open like a shell. Active exercise of the arm.

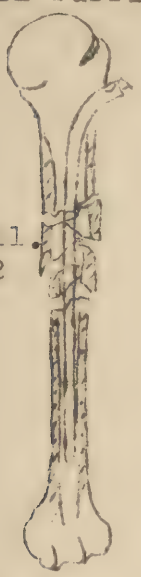
The cast is to be removed after five weeks.

d) Comminuted compound fractures in the second and third sections.

"suitable"

Nailing from below or above. Fracture secure against lateral displacement, probably also against rotation. Stabilization of the

nail sufficient, because the forces acting upon the axis with the possibility of bending it are not great. Shortening improbable because forces shoving the parts together are inconsiderable.



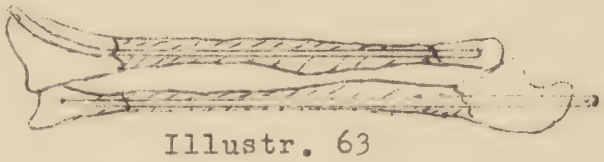
Ill. 62

Additional support (abduction cast) not always required. Nevertheless it is recommended in every case.

D. THE FOREARM

The indication and the kind of after-treatment for fractures of the forearm are comparatively simple. Thus, it may suffice to give here the general directions.

All those fractures are suitable for the nailing operation the short fragment of which has a marrow cavity which is long enough that the nail may get a firm hold (Ill. 63). In the case of the typical radius fracture the boundary is near the wrist at the ulna near the elbow joint, because the nail finds sufficient hold in the spongy bone of the olecranon. If both bones are broken, both of them must be nailed. An additional bandage will be required very seldom if the nails penetrate nearly the whole length of the marrow cavities. In that case it does not make any difference, where the fracture lies. The marrow cavity of the ulna as well as that of the radius are shaped conically. Only with a very long nail will it be possible to achieve a sufficient friction with the bone. Even if the forces leading to a displacement are very slight it was surprisingly often observed that short nails inserted into the olecranon and at the styloid process will work out. A bending of the axis is almost impossible, since nailed fractures support one another.



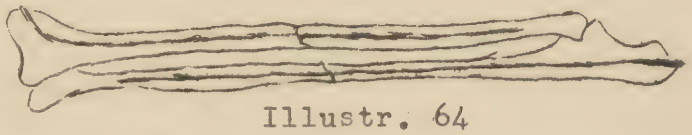
Illustr. 63

Some examples:

a) Transverse fracture in the center of the forearm

"very suitable"

It is well protected against all kinds of displacement by the friction between the nail and the bone, Hirth-teeth, by the standing one upon the other of the bone tubes and by the fact that the two bones support each other.



Illustr. 64

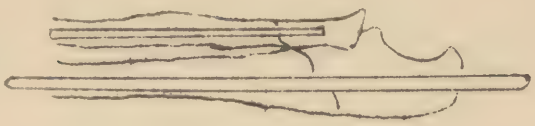
Additional bandage not required.
Exercises immediately possible.

b) Fracture of the forearm near the elbow-joint

"very suitable"

Nailing of the radius in a typical way. For the ulna a special nail is required which must be considerably strengthened in the third near the head end. The reason for this is that strong bending forces will be active with this fracture which must be neutralized exclusively by the nail. A short thick nail is not so

suitable because it shows the tendency to wander out of the bone because of the slight friction in the long fracture piece. Besides this the nail end must be very broad (see page 19).



Illustr. 65

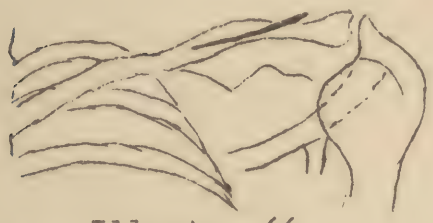
The fracture is well protected against all kinds of displacement.

Additional bandage not required.

Exercise possible immediately.

E. COLLARBONE

The indication for the nailing of the clavicle will be given only occasionally. In nearly all cases a purely functional treatment will lead to a quick and satisfactory healing. If the surgeon does want to nail in spite of that it must be taken into consideration that very few collarbones have a marrow cavity big enough for the nail and that in cases it will be necessary to drill hole into the bone for the nail. In very few cases will the reposition be possible without an exposure of the fracture site.



Illustr. 66
Marrow-Nail in the collarbone

4. SUITABLE TIME AND PRELIMINARY TREATMENT.

As a rule the nailing operation will be the easier the earlier it takes place after the accident. In any case a shortening of the muscles must be prevented. If this does occur it might be impossible to obtain sufficient extension, in spite of the application of great force, to permit the reduction of the bone ends, especially in a fracture of the femur. The reduction will be most successful within the first few hours after the accident. There will then be no difficulties at all. If the operation must be postponed for a couple of days, a wire extension is to be recommended for the thigh fracture. The traction apparatus is insufficient and frequently causes ulcers by the pressure. This will happen very easily, because the most frequent cause for a postponement of the nailing operation will be the shock effect upon the patient. The patient must not be nailed during shock. This corresponds to the general rules of surgery, of course, Even shortly after shock the patient must not be nailed, because the indication for the nailing is never urgent. As experience has shown the danger is very great even for some time after recovery from shock.

The entering of small particles of fat into the lungs must be expected (MAATZ). It is, however, so negligible that with patients who are in good conditions of health, that it never appears clinically after the nailing unless there are additional severe injuries. With endangered patients with multiple fractures, however, it may prove fatal. Therefore, an additional operative shock and an additional fat embolism must be prevented. If an unusual bruising of fat-tissue of the thigh (kind of trauma, marked edema of all the soft parts with large contusions) is to be

supposed the patient must not be nialed even if he does not show signs of a fat embolism. During the nailing operation the tissu must be moved more or less violently and handled. By this a massive displacement of fat may occur. The insertion of the foreign body into the marrow cavity will probably be only of subordinate significance.

The closed thigh fracture will therefore be treated temporarily with a wire (skeletal) extension if the nailing cannot be performed on the day of the accident.

The adjustment of the fracture ends thus being made easy the surgeon will save much time and trouble by this comparatively small operation, while the period of waiting is tolerated much better by the patient.

If an old thigh fracture with considerable shortening must be operated, it will be indispensable to apply first a wire extension. Even if the fractures are many months old, and if the fracture ends stand far from each other an adjustment of their lengths will be possible in a few days by the use of the skeletal traction apparatus.

The leg, the forearm and the arm above the elbow may be conserved by applying the Kramer or Volkmann splint. An early nailing is recommended also for the leg. It will be easier to nail before a more marked swelling sets in. Blisters caused by the nailing will occur only seldom and the earlier the fracture is ideally reduced by nailing the less frequently will a necrosis by pressure occur.

5. NARCOSIS

The kind of narcosis to be used depends on the expected duration of the operation and the necessity of obtaining complete relaxation of the muscles for the reduction of the fracture. In the thigh a nailing will be impossible without sufficient relaxation of the muscles. For this purpose the spinal anaesthesia will be very useful. Children, juveniles and adults under 40 years are to be treated with ether narcosis only when the spinal anesthesia is considered to be an unnecessary danger to patients of that age. In the leg, the forearm and arm above the elbow Evipanrausch (short Evipan anaesthesia) will usually suffice and it may be extended to an ether narcosis if necessary. Children must be treated only with ether. As a return of the tonus of the muscles is to be desired (see after-treatment) the narcosis should not last any longer nor should it be deeper than necessary. All these considerations have to be taken into consideration, when the question has to be decided to what kind of narcosis should be applied. It will, of course, be influenced largely by the custom of the hospital concerned.

So far only nailing of the forearm has been attempted under local anaesthesia. Infiltration at the place of the insertion of the nail and fracture site suffices. Our knowledge of the sensitiveness to pain of the marrow cavity is still rather insufficient. Some patients have no trouble at all, other complain about intense pain.

6. APPROPRIATE POSITION AND ADJUSTMENT.

The proper arrangement of the patient should make possible a good extension, permit easy insertion of the nail and leave room enough for the X-ray and the repositioning apparatus. Thus a free suspension of the extremity concerned will be superior to the position in extension splints. Hooks in the walls and ceiling and block-and-tackle are very useful. Too much attention cannot be given to the proper arrangement of the patient in order to obtain a good extension. Before speaking of the different positions and the various devices and gadgets required for the several bones the fundamental technique of the reduction of the fracture must be discussed. A reduction by hand before the fluoroscopic screen may be possible in some cases. But it cannot be a prolonged procedure because injurious effects upon the hands would be inevitable. Apart from this there are cases which require a lateral force for the reduction of such strength as cannot be achieved by hand. Many difficulties will be encountered in maintaining the right position in the one plane during the radioscopy and reduction in the second plane if all this is done by hand. Therefore special tools are required. The simplest device of course are two straps which may be held in the appropriate position by one or more persons (traction and counter traction). In many cases the surgeon will get along with this arrangement very well. In order to be successful in every cases better tools will be required. The above mentioned repositioning apparatus has proved to be a great help. The handling of it is very simle. Its grasping hands are practically lengthened arm of the individual carrying out the reduction. When reduction is obtained in one plane the position may be held by a regulating screw while the fixation in the second plane is accomplished. The apparatus does not work with rough force but allows a skilful loosening of jammed fragments and free manipulation of the fragments in order to achieve the most favorable position for the reduction of the fracture. Its manipulation will be decribed in detail under the heading "Tools". This apparatus will be unsatisfactory only when sufficient extension of the fracture cannot be achieved, and in cases where great force is required.

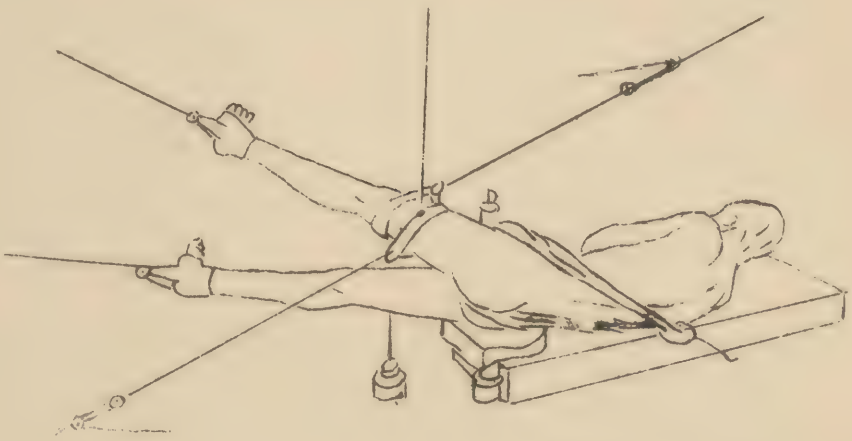
In these cases or, if a repositioning apparatus is not available, a block-and tackle will be a very great help. A femur fracture near the knee-joint may require a strong lateral force to align short fragments. Often this force may be achieved only by using a block-and-tackle. If a sufficient extension of the fracture cannot be achieved the reduction of the fracture ends can sometimes be attained only by a strong bending at the fracture site on the principle described under osteotomy (Ill. 67)

Ill. 67

The reduction of the fragments should not be undertaken until one is ready to insert the guide rod or the nail into the distal fragment. Thus an unnecessary prolonged manipulation of the soft parts is avoided, apart from the fact that in some cases the inserted nail may well serve as an aid for the reduction.

A thigh fracture is to be operated with the patient lying on his side (Ill. 68). The

patient must rest on the sound leg. The hips are bent a little. This posture makes the extreme adduction of the thigh unnecessary. This arrangement makes the nailing possible even in abduction. This will be of special significance in the case of a stiffened hip-joint. The legs are spread. In this way it will be possible to apply various forces, to reduce and to X-ray comfortably. On almost every extension table one can improvise such an arrangement. The essential factor is that both legs are attached to the same extension bar, or , that both extension bars may be moved to the same side of the table. It is recommended to construct a particularly broad pelvis support which allows a lateral posture of the pelvis. A stocking bandage stuffed with cotton-wool must be wrapped round the hip of the injured thigh for counter-traction. By the interposition of spring scales it must be fastened sideways on the upper end of the table. In this way one can measure approximately the force of the traction produced at the fracture site. With a correct preliminary treatment (early operation or previous putting of the fracture in a wire extension) 60 kilograms will seldom have to be exceeded. The traction itself is attached to the foot by a canvas anklet.



Illustr. 68

One of the X-ray tubes must be put between the legs and the other at the stretched side of the thigh so that the surgeon may work near the bent side.

The reduction is then done according to the technique described at the beginning of this section at the very moment when the guide rod is to be inserted into the marrow cavity of the pedistal fragment. In special cases another technique must be applied. With fractures near the hip joint only one arm of the repositioning apparatus is used. It guides the long fracture piece whilst the short one is guided by the surgeon with the inserted nail. With comminuted compound fractures the use of the reposition apparatus and block-and-tackle at the same time may be desirable in order to provide sufficient control for the central fragment.

In order to keep the leg accessible on all sides it should also rest on the extension table. The patient lies on his back. The injured leg is put into a leg support. The knee-joint is bent by about 45°, the leg is extended horizontally. The leg support lies near the thigh with its longer section in order to keep the leg free. Counter traction is not required. The traction apparatus is attached to the leg with anklet made of canvas.

The X-ray apparatus as well as the repositioning apparatus may be readily used. The sound leg hangs down vertically.

If a repositioning apparatus is not available or if the reduction requires stronger force (old fracture, application of a spread nail), a modified Boehler-extension apparatus may be used with excellent result. The apparatus is supplemented by some longitudinal bars to which movable hooks are attached. Small anklets and block-and tackle allow an easy and secure adjustment. They can be worked in four different planes (generally only two will be required). To overcome a strong resistance which may be encountered with old fractures this method is to be preferred to the use of the repositioning apparatus. The use of the gluoroscope screen is somewhat difficult. A small screen is required. The requirement is based upon the special situation in the leg nailing, as dealt with in detail in the chapter "After-treatment".

The arm above the elbow also must be nailed with the patient in a supine position. The patient lies on a firmly fixed stretcher, the shoulder-joint of the injured arm touches the end of the stretcher. The traction apparatus is attached to a wristband. The arm is extended in the elbow joint and stretched away from the body at an angle of 45%. The counter traction apparatus is attached to the armpit on the same side by a broad padded linen strip. The belt runs across the breast and back in a direction opposite to the pulling force.

Generally the reduction will be made easy by using this apparatus. If the place of insertion of the nail and the fracture site are close together it is recommended that the arm be draped aseptically. A small hole in the cloth keeps the skin free at the operation site. The operating surgeon and his assistant work aseptically. Sometimes the reduction is done by hand. In that case the reduction may be facilitated effectively by some side traction apparatus, attached and tested previously. This procedure is described in detail for the forearm, because it is of greater importance for it. The asepsis of the assistant will be of great advantage in the nailing of the arm above the elbow, because the help of an assistant is needed especially for drilling a hole in the bone.

The reduction of the forearm must be done with special care, since, owing to the lack of sufficient space a maximum utilization of the space available is required. As good facilities as possible should be available for the application of the repositioning apparatus, because the adjustment of the fracture often is very difficult in many cases.

The patient lies on his back on a firmly fixed stretcher. The arm above the elbow is extended at right angles to the body. The elbow joint is bent at right angle. The traction apparatus grips all the fingers by so-called "devil-finger". The pulling force is distributed equally upon the fingers by threading a cord to and from through small wheels at the rings attached to the devil fingers and the traction apparatus. The block-and-tackle then attaches to the handle of the traction apparatus. The counter traction apparatus is attached to the arm above the elbow by a broad padded linen strip and traction is exerted in the direction of the body axis towards the head. An additional counter traction is applied to the foot of the opposite side and anklet and traction is exerted in the direction of the body-axis towards the feet with a block-and-tackle in order to fix the body of the patient who will stretch when traction is applied at his hand.

The block-and-tackle applied to the hand works prrallel to the body axis in the direction of the feet. If the so-called "Goose-neck"(X-ray apparatus of Pohl) is not available, the tube of which can be inserted into a narrow space the arm must be moved around maintaining the 90° angle at the elbow joint until there is sufficient space for a larger X-ray apparatus so as to make a horizontal radioscopy possible.

He who forgets the counter traction at the foot will gradually drag the whole body of the patient across the taut counter traction apparatus at the olecranon and extension will be achieved only for a few seconds.

The repositioning apparatus will be used with excellent result in the case of a typical forearm nailing i.e., when the nail must be introduced percutaneously at the olecranon and at the styloid process radii and if the fracture lies in the central thi If the fracture lies near the elbow-joint or near the wrist it is recommended to use auxiliary straps which may be worked by hand. They are applied to the skin with the varnish "Mastisol" before the beginning of the operation. The forearm must be stretched well and securely in order to prevent a lateral displacement. Their suitable direction must be tested thoroughly. They take effect at the very moment the guiding rod is inserted into the marrow cavity of the second fragment. The time expended on the preparations will be saved during the operation. Exposure of the fracture site commonly to be observed especially with the forearm may thus be prevented. An interposition of soft parts must not be a justification.

7. FLUOROSCOPY

It may seem surprising that a whole section of this book should be devoted to fluoroscopy. Observations made both in our own and in other hospitals, however, have led to the conclusion that it is not superfluous to do so. When the technique of the marrow nail operation is adopted by a hospital so many demands will be made on the attention and the energies of the staff by technical questions concerning the operation that generally the fluoroscopy will be somewhat neglected. In comparing the different precautionary measures observed in the X-ray stations with the methods adopted during the marrow nailing the latter will seem positively ruthless. This almost grotesque difference can be explained only by the fact that people no longer realize sufficiently the injurious effect of radioscopy upon the body.

To the patient the danger is certainly not so great because the operation is a solitary event in his life. The operating surgeon, the assistant and the rest of the staff concerned, however, are exposed to a great risk nearly every day, just as with cases requiring radioscopy.

But the patient too may come to grief. In some difficult cases the reduction may require as long as two hours, especially if it is done by unskilled personnel. In many cases the patient will be exposed to the X-ray beams far too long. The tube is generally brought rather close to the limb in order to get a distinct picture on the screen. Thus the patient may often get an overdose so that the skin may be hurt. Therefore the operating surgeon is urgently requested not to overlook this fact because of the great technical difficulties involved in some cases.

Besides this we must not forget that there are some X-ray apparatuses with which the covering of the tube heats up after protracted use, and this may lead to thermic burns of the skin. The sound thigh especially is greatly endangered because it lies close to the tube during the fluoroscopy. An insulating layer, f. i. made of cellulose may prevent this.

The operating surgeon and his assistant are certainly endangered much more. The war conditions will not allow for some time yet a joining of all transportable X-ray apparatus with the fluoroscopyc screen or their being furnished with the required protective screen (made of lead sulphide). Many beams will reach those persons near the observing doctor. Therefore it is quite wrong to use a screen as small and as light as possible for reasons of convenience. The larger screen will afford a better protection. The situation is favorable, when the tube can be brought so close to the fracture site, or when the screen is so large that no beams can pass its rims. Nevertheless, the number of secondary beams will remain alarmingly great.

The following directions are to be given under the present circumstances:

The time required for the fluoroscopy must be as short as possible. It would be advisable to instruct the technical assistant to flash up every view for one second only. For a skilled individual this time will suffice for his orientation.

For this purpose, good adaptation is required. It is advisable to operate in dim white light or better even in red light. All manipulations of the operating surgeon are possible in dim light.

Tube and screen must be brought so close together, or the light should be turned off so much that the beams reach only the screen. If necessary a small diaphragm made of lead should be constructed.

The creen must be carried with the hand well protected by lead gloves.

All persons working near the patient should wear a lead apron.

A transportable X-ray apparatus is absolutely required. It is still better to have two, because one may not work. If the surgeon does not want to expose the fracture it will often be necessary to interrupt the operation. The easiest way is to nail the leg without X-ray control. This should, however, be done only if absolutely necessary, nor will it always be successfull.

Especially suitable are the so-called "Schwanenhaelse" (swan's necks) furnished by the firm of Pohl. They are a small, efficient X-ray apparatus. Thanks to the small size of the tube and to three joints attached to the apparatus, the tube may be inserted into very small spaces, no loss of space being caused by the support of the apparatus.

8. ASEPSIS

The asepsis may be endangered by the fact that one has to work in the dark during the fluoroscopy and above all by the small space at one's disposal. If the fracture is reduced by hand the assistant may work aseptically too. In that case the whole section of the limb must be wrapped up aseptically. The asepsis is considerably endangered by the fluoroscope or the fluoroscopic screen. Therefore a clean separation of the space required by the operating surgeon and the reducing surgeon is desirable. This separation is absolutely necessary if the reduction is not done by hand. The more exact it is the easier it will be for each to keep within his limits. Therefore it is recommended to erect a separating "wall" (in the proper sense of the word) . The wire frame which is covered with a cloth has a separating wall 4 centimeters high near the aperture in the cloth. From outside the screen may be put against this little wall even in the dark. The cloth with the aperture and the wire frame must be pasted broadly over the trochanter with mastisol. The side on which the operating surgeon works must be screened off by a large cloth. During the fluoroscopy required for ascertaining the position of the guiding rod a small cloth which must be renewed each time must be put over the site of the operation, since the screen encroaches on the space required by the operating surgeon. This control will be required less often as the surgeon becomes more experienced. He will then be able to "feel" his way into the marrow cavity, so that control of the position of the guiding rod within reach of the repositioning surgeon i.e. near the fracture site in the non-aseptic area, is quite sufficient.

Also in the case of thigh fractures near the body a separation of the operating surgeon working aseptically and the surgeon who does the reducing and who works non-aseptically is to be recommended. The latter has to direct only the fracture piece distant from the body, whereas the surgeon doing the nailing directs the one near the body.

The above described separation is easily achieved when the leg is concerned. The cloth-covered wire frame covers up the bent knee-joint.

In the arm above the elbow and the forearm one will prefer a complete protective cover the closer the place of the insertion of the nail lies to the fracture site. The small space available makes a separation difficult. Nevertheless, it must be accomplished when using the repositioning apparatus. See chapter " Proper position of the fracture ends". The traction straps described there must be fastened before the protective cover is attached and they must be tested as to their capacity. For the operation wound, slits in the cloth 1 - 2 centimeters long, will suffice. Here also the cloths must be pasted upon the skin near the aperture. The auxiliary traction straps must be covered up too. Their ends will of course project from the aseptic area.

9. SELECTION OF THE NAIL

The length, thickness and shape of the nail depend on the thickness and shape of the bone as well as one the position and the kind of fracture. It must be emphasized once more that the success of the nailing operation depends on the nail being fixed in the marrow cavity of the two fragments as firmly as possible. In using a thin nail the operation will be easy of course but

success is not certain. Therefore, the diameter of the marrow cavity should be ascertained accurately at its narrowest part. At a focal distance of 75 centimeters the average record on the plate will amount to about 1 millimeter. It is also possible to hold the probably suitable nail beside the limb, when taking another X-ray so that it will be possible to take a comparative measurement, as the distorsion will be the same (EHRLICH). To use a "Metalltreppe" (a scale made of metal) will be even better, because it is simpler. It is furnished with a strip of leather and a counterweight and is put on the fracture at the level of the bone, when the first X-ray is taken. The same record will be obtained when the central beam is put between the scale and the middle of the bone. Each grade of the scale is 2 millimeters long. The grades run in the direction of the axis of the extremity. In this way the bending out of line of the scale will not become a source of mistakes. So, even with the first X-ray the width of the marrow cavity can be read.

For the thigh it is preferable to use a thinner nail. The marrow cavity which is largely of the same width affords a sufficient friction. With a nail which is too thick, however, the friction may become so strong that the nail jams. During every operation all the three different widths of the selected nail should be available (see insertion of the nail).

For the leg it is recommended to use a nail as thick as possible. Here the marrow cavity is narrow only for a short distance. The nail may be driven in with some force because it will enter easily thanks to the elasticity of its cross section. So there is the advantage that the nail jams in the marrow cavity to as large an extent as possible.

For the arm above the elbow it will seldom be possible to select a nail corresponding to the diameter of the marrow cavity since its lateral insertion is rather difficult in this case. If, however, the surgeon selects a nail which is some millimeters thinner than the measured width the nailing will be successful and the two nails will provide a sufficient hold. If the fracture lies near the elbow joint the nail should be so thin that is certainly cannot jam in the tapering marrow cavity at the elbow joint. For the stable osteosynthesis the jamming will not suffice anyhow, a plaster cast will be required and the jamming to be feared would lead to a blocking caused by the nail. In such a case we have to speak of a "bolting".

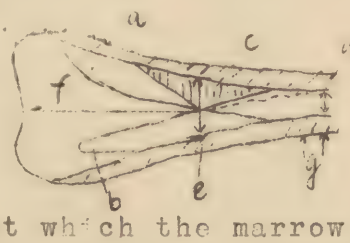
For the forearm in most cases a rather thin nail must be selected for a typical nailing operation, since ulna and radius have rather thin marrow cavities in their tapering parts. This disadvantage will be offset by the fact that long nails may jam at many points of the marrow cavity along the whole length of the bone. Short nail, however, inserted from the side and nearer to the fracture site should and may be thicker. Their being inserted from the side will, however, make it impossible to utilize fully the thickness corresponding to the diameter of the marrow cavity. The hold provided by such nails is not sufficient. Here, also we have to speak of a "bolting".

The length of the nail is of some importance only in connection with fractures near the joint, which are at the same time distant from the place of insertion. In such a case one must not miscalculate. Even one millimeter may be valuable or cause trouble.

In case of all other fractures one should bear in mind that too deep an insertion of the nail into the peripheral fracture piece can only be superfluous and will never cause trouble or be disadvantageous. The length may be measured best on the sound extremity, at the thigh from the end of the trochanter to the slit of the knee-joint. From the slit of the knee-joint upwards one has to subtract 3 centimeters. At the trochanter one must add 3 centimeters for the part of the nail sticking out so that the measured length corresponds to the allowed length of the nail.

On the leg one measures from the dimple between the sinews of the extensor digitorum longus and the tibialis anterior muscle at the heigh of the ligamentum cruciatum curis to the middle of the tuberositas tibiae. Because the nail should be at least always 1 centimeter distant from the joint plane of the foot, the measured distance corresponds to the desired length of the nail. For the bending 1 centimeter must be allowed. The leg nail should be as long as possible.

Special attention must be given to the selection of the leg spread nail. What chiefly matters is that the inclined plane of the outer nail, which pushes the inner nail backwards should have the right position. If the inclined plane comes to lie in that part of the marrow cavity which is too wide it will be ineffectual because the counter pressure of the bone will be lacking. The end of the inclined plane lies at the spot at which the marrow cavity is just sufficiently wide for the two nails (e.). It will be advisable to measure it distally, i.e. fro the foot joint plane. Since the nail point should be 1 centimeter distant from this spot, that centimeter must he subtracted (f-1 centimeter - distance of the end of the inclined plane from the nail tip) (Ill.69)



Ill.

In the arm above the elbow the distance from the intended insertion place to the usual insertion place near the elbow joint should be measured if the nail is introduced from above, as the marrow cavity ends there. If the head of the arm bone is to be taken hold of too, i.e., if the nail must be inserted in an upside-down direction, the measure should be applied at the corresponding spot.

For the forearm it is preferable to take a nail as long as possible if it is a case of a typical nailing. In this way the fractures are best secured. A wandering out of the nail, observed especially in the forearm near the elbow joint as well as at the wrist, is made impossible. For the radius the nail must reach from the styloid process as far as 2 centimeters from the head of the radius, and in the ulna from the olecranon as far as 2 centimeters from the styloid process.

The longitudinal profile of the nail is generally determined and prescribed. Nevertheless, it is recommended to modify that shape in special cases. In Northern Germany the straight thigh nail is generally used. It is easy to insert in the slightly bowed bone. In other parts of Germany the bones are sometimes bent so much that the nail too has to be bent before its insertion. But one cannot depend on its following the shape of the bone. If the fracture site is near the greater curvature of the bone there is the danger of a splitting of the bone. Even though the splitting of a straight thigh bone by a jamming marrow nail is hardly possible, a large piece of the cortex may

easily be broken off of the greater curvature of a bowed bone, if the nail is driven only against one side of the bone.

Ill.70

In the leg the middle part of the nail should always be straight, in order to prevent a recurvation. It is recommended to give to the inner nail a stronger curve than to the outer nail, in order to achieve a better jamming. It should be emphasized that the surgeon who is not yet fully skilled in this operation will do well to insert the double nails one at a time. Later, when greater skill has been acquired they can be driven in at the same time.

The nail for the arm above the elbow too should be as straight as possible in its middle part. If a short fragment is entered for only a short distance by the tip of the nail that tip should not be curved.

With the forearm the nail for the radius only should be bent somewhat at the head end. Thus no forces can act upon the wrist when the nail is once fixed. In order to facilitate the insertion the nail should be bent only after about two thirds of it have entered the bone. Otherwise the nail remains straight. For the ulna a nail of a straight shape is always used. (Ill. 71)

Ill.71

For a fracture near the elbow-joint a special nail is used, which is thicker than the other forearm nails and tapers at its end. This shape is required since the nail should be fixed very firmly at the fracture site. At the same time it must be driven into the ulna so deep that it cannot work itself out of the bone. The nail end must be particularly broad so as to find sufficient hold in the spongy bone. A thin nail will cut the soft spongiosa (see chapter I).

10. INSERTION OF THE GUIDE ROD

In order to facilitate the introduction of the nail into the proximal marrow cavity a guide rod is used for the nailing of the femur and the ulna. At the same time this has the advantage that the guide rod can easily be pushed forward at the moment of a successful reduction in order to maintain the required position of the fragments. When the nail is driven in by blows with a hammer an unintentional displacement of the fragments may easily occur. Whereas a guide rod wrongly placed may easily be taken out again, the striking out of a nail may offer considerable difficulty especially in the thigh. In a nailing of the ulna it will be a great advantage if the guide rod is inserted into the distal marrow cavity a short way at the moment of a successful reduction. This technique would be helpful also in the radius. Here, however, it will be advisable not to use the guide rod, in order to avoid all the stress not absolutely required which might cause a breaking of the bone at the bone at the styloid process near the wrist.

Both guide rod and nail must have the necessary free play. Only suitable sized instruments may be used, If the guide rod is fixed too tight in the nail a jamming may occur the moment the nail is inserted, since the nail shows a tendency to adapt itself to the shape of the bone and must be free to bend more or less.

For the insertion of the guide rod at the thigh the direction of the marrow cavity must be indicated on the lateral and posterior sides of the thigh with a skin pencil. Those lines are determined during the horizontal and vertical radioscopy. To protect the hands from exposure to the X-ray beams during the radioscopy it is recommended to use a long guide rod which must be brought into the direction of the marrow cavity. The lines will then be marked upon the skin accordingly. It is obvious that the direction of the marrow cavity of only the proximal fragment is important. The lines are extended proximally and distally for the entire length of the thigh. If the radioscopic planes are correct both lines must meet near the trochanter and at the insertion spot of the guide rod. Nevertheless it will often occur that the point of intersection is farther in the direction of the trunk. So it is of no value for determining the spot for insertion of the guide rod. It will be better to go by the palpation finding. The trochanter tip can be felt easily even with corpulent people. A stab incision 2 centimeters long is made slightly in the direction of the head and medially from the tip. Then the guide rod is inserted into the trochanter. One may also drill a little hole into the bone with the awl. After that the guide rod is pushed forward by hand, turning it slightly. In this way the guide rod will not jam too much in the trochanter, and it will be much easier for the surgeon to feel whether the guide enters into the marrow cavity, or whether it is in a wrong direction or not. The direction lines of the marrow cavity indicate how the guide rod is to be held. The upper part of the thigh being covered with sterile drapes and the marcation being covered up also, the marcation lines should be extended onto the lower part of the thigh as described above.

The guide rod must not be too sharp at its tip. Otherwise it may occur that it jams laterally in the corticalis. This fact must be taken into consideration especially with children's bones.

After a short time the surgeon will get an excellent sense of whether the guide rod is in the right position or not, so that additional radioscopy is required only when the tip of the guide rod approaches the fracture site. If, however, the insertion should prove difficult, it will be better to desist from making further attemtps and to ascertain the right position using the screen, In case it is faulty it will be advisable to make another insertion. Otherwise the guide rod might slip again and again into its former position. There can be no objection to pushing the guide rod forward by slight hammer strokes. As soon as the surgeon has a certain esperience the sound of the instruments and the success of each stroke of the hammer will indicate to him whether he is making satisfactory progress or not.

The insertion of the guide rod may be rather difficult in the case of a fracture very high in the upper part of the bone. If the short fragment is in abduction it will in rare cases be necessary to use a strong so-called Schanz Dorn (a prick-punch constructed by Schanz). If inserted percutaneously and laterally into the trochanter it will be a convenient handle until the guide rod is introduced and the reduction is achieved. If the short fragment stands in an adducted position this may lead to an increased adduction of the guide rod. The tip of the guide rod

then shows a tendency to jam in the corticalis (outside). A vicious circle will be the consequence. The insertion of the guide rod will, however, be considerably facilitated if a traction strap is attached to the short fragment before the operation, which by pulling in an outward direction will give a certain stability to the short fragment.

It will not be difficult to introduce the nail into the distal fracture piece after a successful reduction. In the ulna the guide rod is inserted through an incision in the skin ½ centimeter long, at that point of the olecranon where the extended marrow cavity of the bone is supposed to be. There the guide rod must be drilled in or driven in. This spot can easily be determined by touch, for, the center of the bone can be felt distinctly. Appropriate X-ray control in both planes will be a good protection against any mistake.

11. THE INSERTION OF THE NAIL

By way of introduction something shall be said about the technique of nailing. Generally the surgeon will be inclined to introduce the nail with many light careful strokes of a hammer. It is better, however, to insert the nail with some powerful strokes driving the nail well home. Thus the bone is not shaken so much. A continuous striking upon the bone will often lead to an infiltration of fat into the blood vessels (LARSEN). Besides that the striking in of nails in a workmanlike way is less tedious and much more elegant.

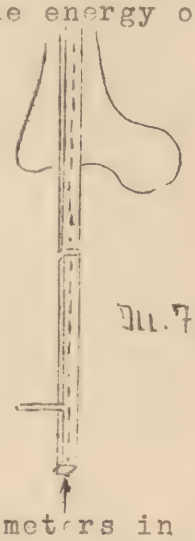
It is not at all difficult to insert the nail into the thigh, as soon as the selection of the nail and the position of the guide rod are correct. It does not make any difference, whether the guide rod is inserted first into the two fragments or into the proximal fragment after the distal fragment has been pierced slightly by the guide rod. The latter method is preferable only when the fracture-piece near the body is short so that it must be guided with the nail during the reduction.

The nail being elastic and flexible on all sides it is of no importance at all to which side its open part is directed. The resistance is fairly strong, while it is inserted into the trochanter. As soon as it has entered the marrow cavity in the right way it will penetrate about 2 - 3 centimeters with each stroke of a hammer weighing about ½ kilograms. A splitting of the bone is not to be feared, more likely it will get stuck in the marrow cavity. One must, however, see to it carefully that the nail is not driven in subtrochanterally through the compacta. This may happen when the guide rod driven in by hammer strokes first pierces the compacta and reaches the marrow cavity only afterwards, In such a case there is danger of splitting the bone (Ill. 72).

Ill. 72

Since the degree of friction between the nail and the bone depends largely on the small ridges in the marrow cavity, it may happen again and again that the thickness of the selected nail proves to be unsuitable. If the nail tends to get stuck or if it has not sufficient friction it is preferable to take it out again and to replace it by another nail. The trick is to find

out in time, when the nail first shows a tendency to jam, i.e. when it can still be struck out without difficulty. No doubt this is somewhat risky especially for the beginner. He cannot be careful enough. Therefore it is recommended that the beginner should use a comparatively light hammer, a hammer of half the weight of the normal hammer. The danger that the energy of the hammer will not be sufficient is very slight.

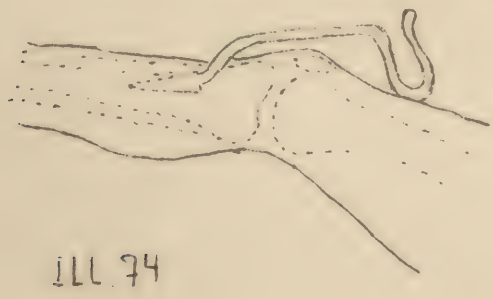


Ill. 73

If the head end of the nail is flush with the end of the guide rod so that the removal of the guide rod is not possible the nail set I for the thigh nail should be used. (Ill. 73).

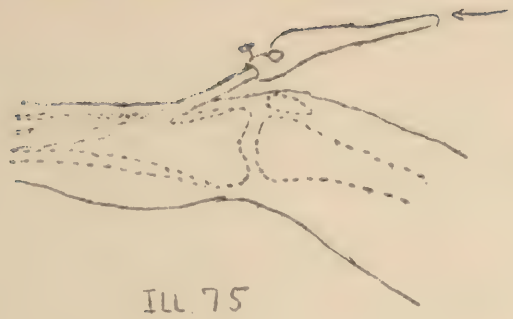
The guide rod may be removed as soon as the nail has penetrated into the distal fragment for some centimeters. The extension is relaxed or taken off altogether so that the fracture pieces stand firmly one upon the other. The chief thing is to eliminate any possible faulty rotation and to insert the nail definitively strongly pressing the distal section of the limb against it. It should stick out of the bone 3 centimeters in the case of an adult and 1 - 2 centimeters with children according to their ages. It is very easy to maintain the right distance with the nail set II for the thigh nail.

The <u>leg nail</u> is inserted into the marrow cavity in front at the tuberositas tibiae. The tuberositas must be exposed by a medical or lateral incision. The loose skin is to be turned back and held with a towel clip. The incision should be made in such a way that the lower angle of the wound corresponds to the point of insertion spot on the bone. In this way any unnecessary injury to the wound edges near the knee by the nail or the guide rod which are inserted obliquely is avoided. The awl is applied at the level of the tuberosity and in the middle of it, in a more or less vertical direction. As the awl penetrates deeper into the soft bone the handle should be lowered. The bayonet-shaped awl allows a rather tangential insertion (Ill. 74). In this way the insertion of the nail is considerably facilitated. Even with the first strokes the head end of the nail should be lowered as much as possible in order to facilitate an easy sliding along of the nail on the inner back wall of the marrow cavity. The nail should point toward the second toe. A well skilled surgeon will easily find out whether the nail is in the right or wrong position by the resistance encountered in the cavity. If the X-ray control shows that the nail is following along the back wall, a further X-ray in the second plane will be superfluous.



Ill. 74

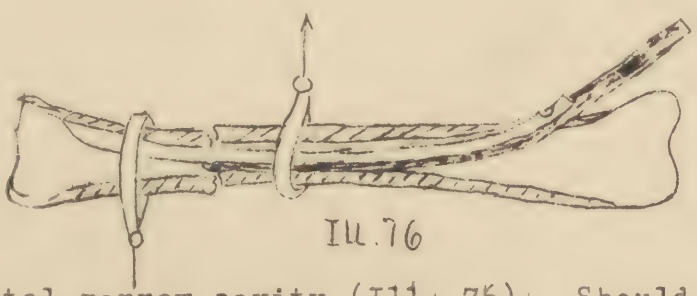
Since the double nail is not uniformly curved, its bending radius being smaller at the ends and the central part nearly straight, the inner and the outer nail must be inserted at the same time. Otherwise A very disagreeable jamming may occur. The insertion is greatly facilitated by the nail set, which transmits the force of the hammer-strokes in the direction of the central part of the nail. (Ill. 75)



Ill. 75

After the nail has penetrated into the distal marrow cavity one must try to achieve as ideal a reduction as possible, which is important for the leg especially with regard to any lateral displacement. At the same time the extention is relaxed a little and the fracture fragments are pressed strongly together.

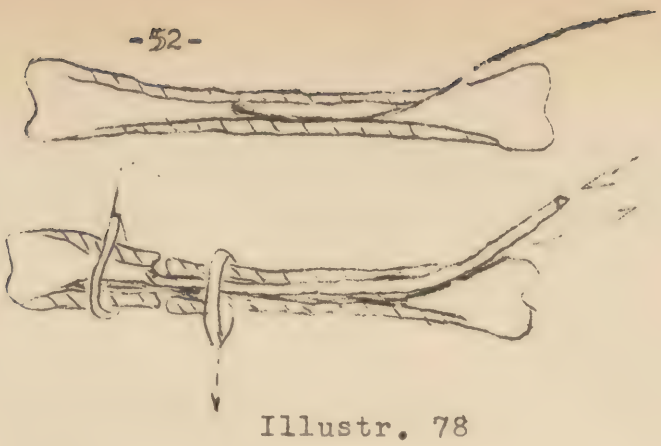
The insertion of a spread nail may be difficult, especially if the spread nail with an inclined plane is used, and in cases where the second nail, i.e. the inner nail tends to break out laterally through the fracture site. Therefore it will be advisa to insert completely the outer nail which bears the inclined plane first. A good protection against a later further penetration of this nail into the marrow cavity is the wire counter traction with attached weight. A dislocation of the fracture with traction and counter traction may then be required (modified Boehler-apparatus with block-and-tackle), in order to facilitate the insertion of the inner nail into the distal marrow cavity (Ill. 76). Should the outer nail penetrate too deep which will definitely occur if the inclined plane lies to far proximally - in that case a piece of the wire counter traction will have to be left deep in the wound as a loop in order to facilitate the later extracti n of the nail. If the plane of the spread is intended to lie in the frontal plane the nails must not be inserted in the middle of the tuberosity but rather by the side of it , and it will then be no difficulty at all in putting the bending plane of the nails and as well as the spread plane in such a way as seems to be most suitable for the shape of the fracture (Ill. 77)



Ill. 76

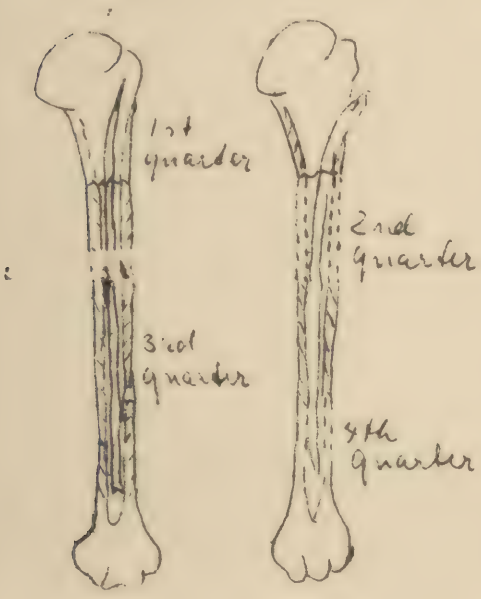
Ill. 77

When the turn-spread nail is used the inner nail must be introduced completely first, and in the beginning in such a position that its distal part is concave shaped to the front. As soon as the point of the nail lies in the wider section of the lower marrow cavity the nail is turned round 180° using a screw driver. This turning must be made before the point of the nail has penetrated into the spongiosa of the distal bone section. During the insertion of the outer nail the completely inserted nail is then protected against further penetration by a holdfast wire or cross-pin which is inserted into an



Illustr. 78

an oblique hole at the nail head provided for this purpose and which finds a firm hold on the tuberositas. If, however, the outer nail should show a tendency to work its way out of the fracture-slit in front, suitable dislocation must be made during its insertion into the marrow cavity (Ill. 78).



Ill. 79

In the arm above the elbow the nail may be introduced at two places i.e. near the elbow joint, or near the shoulder joint. Both places are easy of access and the choice will depend on the site of the fracture. Two considerations are decisive: In the first place the nail is to find a firmer hold in the short fragment by penetrating the corticalis laterally. In the second place an exposure of the fracture hematoma should be avoided. Therefore a very short fragment should not be nailed from the side of the hematoma otherwise the fracture site would be exposed. Fractures in the second and fourth section of the bone should be nailed from above, all the other fractures from below (Ill. 79).

The upper insertion point must be exposed by an incision 5 centimeters over the deltoid muscle. The muscle must be split longitudinally with a crown-gimlet and a hole must be drilled from the side into the corticalis, so that the marrow cavity is opened up. Then the two nails can be inserted obliquely. They should project out of the bone for 1½ centimeter.

If the nail is inserted from below the drill hole is situated about 2 centimeters above the fossa olecrani. Here the marrow cavity may be so flat that an extension of the drill hole upwards may be recuired. At that spot the nail should project out of the bone for about one centimeter.

If the nail inserted from above is too long it must under no circumstances be inserted too deep. Otherwise it would jam in the marrow cavity near the elbow. It would thus push the second fragment along before it and might cause a gap. If in such a case the nail head end should stick out of the bone too far the nail must be changed. In order not to lose the reduction a thin guide rod must be inserted before the nail is removed (if need be a Kirschner - wire may be used).

A special description of the nailing of the ulna is not needed. The straight nail may be inserted with the help of a thin guide rod.

At the radius the insertion point for the nail lies between the sinews of the extensor poll. longus and brevis. Over the middle of the styloid process radii a stab incision 5 centimeters long must be made and a tiny hole must be drilled obliquely into the marrow canal with the awl. X-ray control while the awl is put to the bone will ensure the finding of the right spot. The

nail is always inserted with a slight pressure of the finger away from the wrist. The nail head end is bent before its final insertion (see shape of the nail longitudinal profile). The cutaneous wound is closed with a stitch-suture.

12. THE AFTERTREATMENT

Only a few words need be said about the aftertreatment of a successful nailing. If the possibility of a displacement of the fracture ends is out of the question the moment of the first movement of the limbs and the time for the first weight bearing depend on the general condition of the patient and the extent of the very painful bruising of the soft parts. Effusions of blood into the adjacent joints which used to occur much less frequently when the old methods were in vogue, and which are only partly caused by the forcible extension during the operation may demand a long confinement to bed. When making up a list of a number of cases one is surprised to find how few patients with thigh fractures can or may get up within the first week after the nailing. The number of attendant injuries among which concussion of the brain or skull fractures are particularly frequent, is astonishingly great.

Though experience has shown that the aftertreatment does not give much trouble either to the surgeon or to the nursing personnel the vigilance of the surgeon must be all the greater. In case of insufficient care the number of persons discharged too early only to return to the hospital after few weeks with unexpected dislocations will not be small. Malpositions must be detected at a time when they may be corrected during the "Rausch" (anaesthesia) in order to prevent a later osteotomy.

The aftertreatment begins after the wound has been closed i.e. while the patient is still under the anaesthetic.

1. With nails less difficult to bend (leg and forearm) the proper shape of the nail must be verified using the fluoroscopic screen. The leg nails in particular may require some correction as they very often get bent in the form of a recurvation of the leg during the insertion.

2. The possibilities of a displacement of the fracture ends must be examined as soon as the nail has been inserted. If a bending of the axis is still possible, an additional plaster cast is urgently required. If rotation is possible, an additional plaster cast must be applied if the shape of the fracture makes is probable that even after the return of the muscle tonus the principle of the Hirth teeth is out of the question. If a fixation by the Hirth teeth may be expected a splint which will prevent a tipping over of the limb until the end of the narcosis will suffice. The examination to be made the following day is decisive for the further kind of treatment. In this connection it may be pointed out that, while a large log cannot be dragged with a jerk quickly through viscous mud, this will be easily done with little expenditure of force, if one only has sufficient patience. The friction between the nail and the bone shaft may be strong enough to prevent a quick rotary movement of the unstable foot and still not be strong enough to withstand the constant though small force of the twisted foot.

3. After any smoothening off of the sharp-edged fracture ends the effect of the Hirth-teeth must be disregarded.

4. After the lapse of a couple of weeks the nail will get loose in the marrow cavity. If conditions are favorable the fracture ends may slip longitudinally on the nail without any great danger of rotation. Nevertheless the possibility of an rotation displacement must be taken into consideration.

To avoid unnecessary repetition details about the data of the aftertreatment will be given in the chapter on "Indications" for the same factors which make a fracture more or less suitable for the marrow nailing determine the kind of aftertreatment.

By way of general directions it must be mentioned that active and painless exercises will create the best conditions for the healing of the fracture and the conservation of the strength of the limb. Baths and heat cradles should be frequently used.

Complications during the healing of the wound must be detected early. It would be wrong to delay if a suppuration of the insertion spot is suspected. A prophylactically opened wound will heal quickly, while a wound opened too late may cause inflammation of the fracture hematoma if the fracture lies near the nail insertion spot. A slow spread of the inflammation along the nail is not to be feared if the wound is opened early enough.

The time recuired for treatment in the hospital depends on many external factors. Surgeons not yet fully acquainted with the new method are urged to leave the patient in the hospital as long as possible.

The duration of the patient's stay at the hospital depends on many external factors. It is very important what profession the patient has and what attitude he takes. An office clerk f.i. with a well treated thigh fracture may easily go to his office at his own request after a fortnight. A workman, however, will not be able to go to work again before the lapse of 6-8 weeks even under the most favorable conditions. Of course the clinical finding still will be decisive. It is the responsibility of the surgeon to suggest to the patient the right attitude of mind towards his disease with regard to the new treatment of fractures and the shorter duration of the disease. The surgeon as well as the patient must get used also to the much lower rates of sickness-benefits paid in favorable cases.

Special attention must be paid to the progress of an "aseptic" inflammation of the fracture, until sufficient experience has been gained (Sudeck). Even when the nailing was successful a dystrophic phase may develop (painful swelling, heat, cyanosis, perspiring skin). Early weight bearing seems to bring on these complications. The best treatment for these are rest and the heat cradle.

13. THE REMOVAL OF THE NAIL

In general a nail should be removed after the lapse of three months since a firm bony consolidation of the fracture must be expected by that time.

An earlier removal may be advisable. Reasons for this are:

1. The fragments have become displaced and the nail hinders a new and exact reposition (angulation or rotation).

2. The nail wanders and endagers neighbouring joints or the soft parts covering the nail head end.

3. The nail is bent.

4. The nail is broken.

5. With children to attain a quicker healing of the fracture. Suppuration near the insertion spot or fracture site, however, (osteotomy, complicated fracture) are not indications for a removal of the nail. In the case of a fistula at the nail insertion spot the extraction is even undesirable. It will be advisable to wait as long as possible in general since such fistulas will eventually disappear, whereas an early extraction may lead to a late suppuration near the fracture site. Obviously, the suppuration will spread along the marrow cavity much more easily when the nail has been extracted.

The nail must lie in the bone for more than three months if it is suspected or certain that the fracture has not yet healed properly.

A late consolidation may be caused by:

1. Infection.

2. Distraction of the fragments due to jamming of the nail

3. Insufficient mechanical stabilization of the fracture by the nail.

4. All the other factors which may lead to a delayed formation of callus (Diabetes, Lues and so on). They are generally known from the science of fracture treatment and need not be repeated here.

5. With an osteotomy performed because of a faulty positi after breaking the bone it may be advisable to leave the nail in for a longer term than three months since the normal balance of the muscles is reestablished only slowly. Besides this osteotomy wounds achieve a slower bony healing then recent fractures nailed percutaneously.

The adequate bony healing of the fracture is ascertained by X-ray control. The nail may be extracted as soon as the fracture fissure is bridged over the bone sufficiently and as soon as the callus shows a satisfactory formation of the little streaks.

If this cannot be ascertained beyond doubt the nail should be left in the bone for even though with some fractures the fracture fissure is to be recognized quite distinctly and though it may be firm from the clinical point of view and suitable for weight bearing, this cannot be ascertained beyond doubt as long as the nail is in the bone. Therefore it is better to leave it in. Nails inserted two years previously have not caused any particular harm to the patients concerned. Even though the X-ray picture shows a vigorous formation of callus at the fracture site, it will not be advisable to remove the nail while the design of the callus is soft and cloudy. Callus which appears soft and cloudy in the X-ray is often soft and flexible so that an angulation may occur after the extraction of the nail.

Even though a newly inserted nail may be extremely difficult to extract, nails inserted a couple of weeks or even months before, are generally easy to remove. Loose nails may be extracted under

local anaesthesia (arm above the elbow and forearm) while firmly fixed nails should be removed under Evipan-anaesthesia.

For the thigh the patient must be operated while lying on his side. It may be difficult to find the nail hole if the nail head is covered by a callus cap. The "Siemens" metal-finder by KUENTSCHER is very useful for a quick orientation. If the nail sticks firmly and if the surgeon intends to manage without a large incision of the skin it will be better to use a hammer for removing the nail. With its help every nail will be easily removed. If spread nails with an inclined plane have been used the inner nail must always be removed first. If the turn spread nail has been used the outer one first, since rotation of the inner nail may be impossible because of the marrow callus. The nail which is deformed may require considerable force for its removal.

A broken thigh nail must be removed as soon as possible after this accident has occurred. The patient will soon go to see his doctor, because of the pain at the old fracture site. Frequently an angulation of the thigh will occur. The fracture site is not yet firm, otherwise the nail would not have broken. The break in the nail is not always situated near the fracture site of the bone. The proximal part of the nail is removed first, then the nail catcher (see tools) is introduced and as soon as it has "caught" the remaining piece the nail must be extracted or hammered out. A bending at the fracture site must first be adjusted. The insertion of a fresh nail will not give any trouble.

The finding of the nail head in the leg may be difficult, if it has worked itself deep into the bone, which will happen frequently. Here also the "Siemens" metal-finder will prove very useful. If it is not available it will be advisable to insert a small pin before the screen or to make a small X-ray picture (a-p) with the pin in the right position for the nail head must be sought for beneath the patellar tendon. Sometimes it is perfectly amazing how many centimeters the nail is to be found distant from the place where it was supposed to be either laterally or medially. By the described procedure unnecessary injuries to the patellar tendon are avoided and the associated continuous irritation of the wound, which will occur frequently if the extraction of the nail in the leg is not done carefully. When using a spread nail with inclined plane it must be borne in mind that the nails must be removed one after the other and that the one with an inclined plane can be removed only after the other nail has been extracted.

A broken nail in the leg must also be removed as quickly as possible and must be replaced by a new nail with the same diameter. In order to avoid disturbances at the fracture site the surgeon may desire from an exposure and extract the distal piece of the nail first with the nail tip. The nail tip is exposed at the extensor side of the tibia, then a hole must be drilled into it and it must be extracted in an oblique plane. This is made possible by the elasticity of the nail.

In the arm above the elbow there are no difficulties to be encountered either in finding the nail or in extracting it. In general it can be removed with a hook. An exact X-ray location of the nail head end is recommended if the nail has wandered and has completely entered the marrow cavity, and if the metal finder is not available. If this is the case the marrow cavity must be opened laterally and the nail must be pried out by leverage and extracted on an inclined plane. As regards the forearm only the removal of the radius nail at the ulna which was inserted at the styloid process must be specially mentioned, since during its insertion as well as during its removal an injury to the wrist

must be avoided in any case. Every movement with the lever must be executed in such a way that the bone is not pushed towards the wrist and gets broken. This can be achieved with some care. It must be taken for granted, however, that the nail was correctly formed before its insertion during the first operation, so that it does not show any tendency to wander into the bone. The radius nail as well as the ulna nail can be extracted easily with the hand after the first loosening strokes.

Breaking of nails was observed also with ulna fractures near the elbow joint. This fact proves how strong the forces are which act at that spot. Since there is a straight nail in question the distal nail fragment may be taken out with the small nail catcher (see tools).

14. NAILING IN THE CASE OF AN OPEN FRACTURE

The advantages of marrow nailing are the same both for closed fractures and for those which a primary healing of complicated wounds. Probably primary healing will occur much more frequently with the new method than with the old ones, since bony wounds and those in the soft parts are immobilized better by the nail than by any other method.

The new method shows the following great advantages in the case of a suppuration in the front of the fracture site :

1. The fracture has been ideally fixed. A spreading of the suppuration of the soft parts to the bone is not easily possible. If the bone wound is affected by the inflammation the suppuration will proceed more favorably by reason of the fixation.

2. The extremity is easy of access on all sides. So it can be watched every day and incisions required can be made early.

Disadvantages of the method are:

1. Suppuration may proceed along the nail. In this case it is restricted to the marrow cavity and does not affect the bone tissue (A. W. FISCHER and REICH). Even after the lapse of weeks such an inflammation at the insertion site of the nail may lead to the formation of an abscess under the primarily healed operation wound. After the opening of the abscess the nail acts as a drain for the often very active discharge of pus.

2. At the fracture ends crown-sequestrum or ring sequestrum may develop.

The sequestra are covered by enveloping callus which must be removed after the fixation of the fracture. For the nailing of the marrow cavity of compound fractures the following directions may be given (MAATZ and REICH):

The nailing operation should be done as soon as possible. A limit of hours cannot be fixed but during the course of an infection a nailing must not be performed.

After the subsidence of the initial violent inflammation there comes another moment favorable for the nailing. After having attained a sufficient immunization from the germs in question and after the suppuration has reached the so-called "cold stage"

the body appears to be able to endure a surgical intervention without any injurious consequences (see gunshot fractures).

Additional injuries to the complicated wounds in the soft parts should be avoided in the nailing. Therefore a technique similar to percutaneous nailing is to be recommended. The guide rod should not be inserted in an upward direction as in the case of an osteotomy. Even if there is no X-ray apparatus available the guide rod can be inserted precutaneously after the surgeon has some experience. The reduction and the insertion of the nail into the distal marrow cavity can be controlled by the eye. In the case of small wounds too this should be done before the fluoroscopic screen in order to avoid opening of these wounds further.

If possible complicated wounds should be treated after the rules for the primary excision of wounds with subsequent suture. If the wound is very dirty and if it is impossible to excise it with subsequent suture a debridement must be performed, i. e. the worst dirt and crushed tissue must be removed and then the wound must be left wide open and covered loosely with gauze. In t the case of a formation of pockets a saucerization of the wound is to be recommended, in order to prevent a damming of the secretion. Apposition-sutures are to be rejected. By doing so the wound will be cleaned in the quickest way and secondary healing will be achieved. The latter can be accelerated by later "apposition-sutures". Thus a progressive downward extension of the inflammation is prevented.

The advantage of the accessibility of the limb must be fully utilized in the course of the further treatment of the wound and one should adhere to the principle that by leaving the wound open the discharge of the secretion should be secured early.

An additional cast should be avoided if possible. This, however, will result in a narrowing of the indications. The advantages of the treatment of complicated fractures with the marrow nail depends on the complete stabilization of the fragments and the accessibility of the extremity. If an additional cast seems to be required prior to the nailing there is no indication for the nailing operation. The success of the nailing of an open fracture depends essentially on whether it will be possible to achieve a stabile osteosynthesis with the nail.

In general the extremity must be fixed on a splint, as it is the rule with inflammation processes of the soft parts. In this way a changing of the bandage is easily secured.

The nail should be kept in its position as long as possible, i.e. until a bony healing is achieved. Even a very violent suppuration which seems to be caused by the presence of the nail should not be a reason for a premature removal of the nail, at least never during the first eight to ten weeks. Even though V2A or V4A steel is the least irritant metal to the human body, known so far, the body will cover it with a connective tissue membrane and will try to eject it by suppuration after an infection has occurred. The advantages of nailing are still so great, that an increase of the suppuration can certainly be risked. The formation of callus is certainly not delayed by the nail. Nevertheless, suppurating fractures with an inserted nail will frequently not show the formation of any callus for months. In such cases it is not the nail which is responsible for it but the suppuration. It is always wrong to extract the nail as long as a displacement of the fracture may still occur. This may happen even after the lapse of some months. If a fracture

is well protected against lateral displacement either by cicatrization or callus, a removal of the nail may be allowed if a particularly violent suppuration is to be stopped. The securing of the fracture against angulation must be achieved by an additional cast. Our aim must, however, always remain the bony healing with the inserted nail. Sometimes it will be important not to lose patience and never to forget that complicated fractures will sometimes suppurate for months even without a nail and may not show a tendency to form any callus at all. The most favorable conditions are still achieved by the nail.

15. THE NAILING OF GUNSHOT FRACTURES

Any comparison with open fractures must be avoided. Whereas a wound excision and suture may frequently be made with these, it is not permissible with open fractures.

Owing to the peculiarity of the situation some general rules should be considered:

The nailing operation should be performed as soon as possible. One is, however, not limited to certain hours. A successful operation may be performed at any time (KUENTSCHER). Patients with violent suppuration and high fever will recover astonishingly quickly after the fixation by the nail (KUENTSCHER). Not only a careful operation but also a wide opening of all the wounds is necessary. The insertion spot must be larger than usual and must not be closed by sutures but must be loosely covered with gauze. Adequate drainage must be secured by sufficient counter-incisions. The use of a wound spreader may perhaps be necessary.

In the case of gunshot wounds causing bone defects a metal spreader should be inserted into the nail slit in such a way that the bone ends are at the desired distance from each other (KUENTSCHER). The spreader serves at the same time to keep the wound open.

The insertion of the guide rod from the fracture site is to be avoided because an unnecessary spreading of germs is to be feared an experienced surgeon will easily find the marrow cavity from the trochanter even without X-ray control. Inexperienced surgeons should not nail gunshot fractures at all. Reduction before the fluoroscopic screen is not advisable, since any maltreatment of the tissue must be avoided. It will be better to widen the wound by a straight incision as explained before, in order to be able to control the infection.

With gunshot fractures just as with open infected fractures a favorable course of the inflammation and an undisturbed formation of callus are to be expected only after a stabile osteosynthesis.

After the cleaning of the wound the healing may be accelerated by secondary sutures or by drawing it together with adhesive plaster.

16. NAILING WITH DELAYED FORMATION OF CALLUS

In the case of a delayed formation of callus the nailing is "causal therapeutics" because the slow stabilization of the fracture is in most cases due to mechanical conditions. The nail counteracts the dangerous forces causing lateral displacement and favors the pressing forces which are so beneficial to a bony healing.

A delayed formation of callus will very seldom result in a formation of false joints (BLOCK). It never does so if the fracture site gets favorable mechanical conditions. That is why the technique of nailing with delayed formation of callus differs fundamentally from the procedure in the case of a formation of false joints. It is not necessary to create a new situation favorable to the formation of callus or to break the bones again, to freshen the fragments or to treat them by the so-called "Kirschner splitting open", Beck's drilling or "Brandischer's sawing open". The insertion of the nail and the stabilization of the fragments by way of the marrow cavity will be sufficient. If the fragments are in good position i.e. if the marrow cavities of the two bone fragments are in a good direction the fracture site must not be exposed and percuntaneous nailing should be tried. Otherwise the danger of an infection would be considerably increased. An infection is to be feared especially in those cases of compound fracture, which for some reason or other were not nailed primarily which, however, after the soft tissue healing still should be nailed.

In general the technique of the nailing does not differ much from the usual procedure. The reduction of the fragments may, however, require special measures, if the openings of the marrow cavities are not sufficiently protected. The required displacement will then not be possible either manually or with the repositioning apparatus. Good results were achieved with the extension apparatus by Boehler which was modified by FISCHER-MAATZ. If those forces do not suffice the osteoclast may be of great help. The pains taken will not be wasted if an exposure of the fracture can be avoided. Nevertheless this will not be aviodable in every case.

A sharpening of the nail tip has not answered the purpose. A blunt nail will penetrate the young bone and tissue scar at the fracture site without difficulty and will enter into the distal marrow cavity much more easily than a sharp nail. A sharp nail will injure the compacta and penetrate it. It has proved to be very serviceable to fix some sawtooth immediately below the nail tip (see tools).

If the nail is in good position and if it provides sufficient hold to the fragments the patient should expose the fracture to weight bearing as soon as possible because weight bearing is the best therapeutics for a delayed formation of callus.

In the leg a resection of the fibula is to be considered in order to remove its jamming effect (distraction).

17. THE NAILING OPERATION IN PSEUDARTHROSES

The amazingly quick and abundant formation of callus in nailed fractures and the bridging over of larger gaps between the bone suggested the idea of stabilizing pseudarthroses by a nail. It was to be hoped that after the lapse of some time a bony bridging over of the defect along the nail would take place. In the case of a plain pseudarthrosis, however, with joint planes and joint cartilage a healing could not be expected even by the use of this new method. A bony transformation of broad tissue bridges was not to be regarded as being absolutely impossible. Experiments made for this purpose were unsuccessful. Therefore in the treatment of pseudarthrosis, even when using the marrow nail, one cannot avoid the necessity of creating a fracture area. The pseudarthrosis must be resected to that one fresh bone and comes to stand upon the other. In this case bone substance should be removed very conservatively, in order to prevent unnecessary shortening. It is recommended to open the pseudarthrosis sharply or bluntly and to remove only enough of the bone ends with "Luer's rongeurs" until fresh bone is exposed. Sometimes a widening of the marrow cavity at the bone ends may be necessary. If a shortening of the bone is to be prevented an attempt to split, to saw or to drill the bone with the Beck apparatus will be justified. The technique of the nailing is the same as usual. With the exception of the thigh it will always be advisable to introduce the nail percutaneously before the old fracture is exposed, lest the bone wound which is apt to become infected be kept open unnecessarily long. After a sufficient preparation of the bone ends the nail is then inserted under direct visual control.

18. OSTEOTOMY

Strictly speaking osteotomy is the surgical cutting of a bone. It ist most often done in the case of badly healed bone fractures. The correction by operation of an inborn abnormal curvature or of one acquired by a disease of the bone belongs here as well. With the nailing operation of fresh bone fractures astonishingly great successes were achieved. A large proportion of osteotomies especially in the leg is made possible only by marrow nailing. At any rate the indication for an operation may be given in many cases in which one heretofore rather desisted from an operation because of the uncertainty of success and the disadvantages to be expected, such as a stiffening of the neighbouring joints. The reason for a very cautious indication is the fact that the forces causing lateral displacement which act upon the bone ends are very great after an osteotomy. The muscles will become unbalanced after an osteotomy e. g. in the case of a curvature of the thigh bone several years old, if the fracture has not healed well. The traction and pressure exercised by the transverse section of the muscles (agonists and antagonists) amount to several hundred kilograms even in the case of a fresh fracture. The way in which the bone is affected is defined as angulation by the technician. It appears as an angulation of the fracture site. If one of the muscle groups is stronger, which happens very often with such osteotomies, this angulation will occur much more easily. It could not be prevented with the contrivances previously at our disposal such as ivory bolts, Lane's plates, wiring, plaster cast or extension. The steel nail alone, which is inserted into the marrow cavity, has sufficient mechanical stability.

There are five further reasons why with osteotomies fracture ends are better secured by the nail than by all other methods. Firstly, the procedure is techincally much simpler. Secondly the danger of an infection is much less, because the skin incision can be much smaller than with the application of Lane's plates on two sides of the bone. In the third place, the periosteum need not be removed from the bone, because this is not required for the insertion of the nail. Thus it is possible to avoid the principle of LANGENBECK with its subperiosteal operation in the case of an osteosynthesis. This is most important for the formation of callus to which the periosteum largely contributes. Besides this, the periosteum provides the chief blood supply for the outer bone compact layer. A removal of the periosteum therefore means, without doubt, a serious disadvantage to the blood supply and by this to the defensive forces against infection. All this certainly is a reason for the easy infection of osteotomies. Lastly the removal of the periosteum brings about an enlarging of the wounds which again means an increase of the danger of an infection. In the fourth place foreign bodies attached to the fracture site may easily result in a dealyed formation of callus, whereas the nail lying in the marrow cavity will certainly not retard the formation of young bone tissue. In the fifth and last place there arises the fear of a renewed injury to the muscles and the joints, caused by the necessary prolonged rest of the limb in the plaster cast.

Osteotomies with marrow nailing may be made in case of

1. Bone fractures healed in a faulty position. These are above all shortening, angulation and even after the introduction of marrow nailing, also rotation.

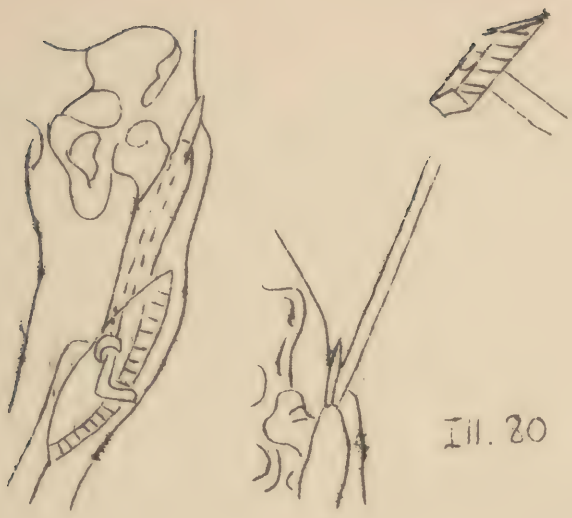
2. Inborn abnormal curvatures of the long bone shafts (not acquired by bone fracture), espec. knock-kneed legs and bandy legs.

3. Lengthening of bone shafts delayed in their growth.

4. Shortening of the bone f. i. to achieve a suture (BOEHLER) of nerves and vessels, or, in rare cases, the equalization of the sound and the diseased side, which may have been shortened f. i. by a compound fracture, and on which a lengthening osteotomy cannot be made (BAUER).

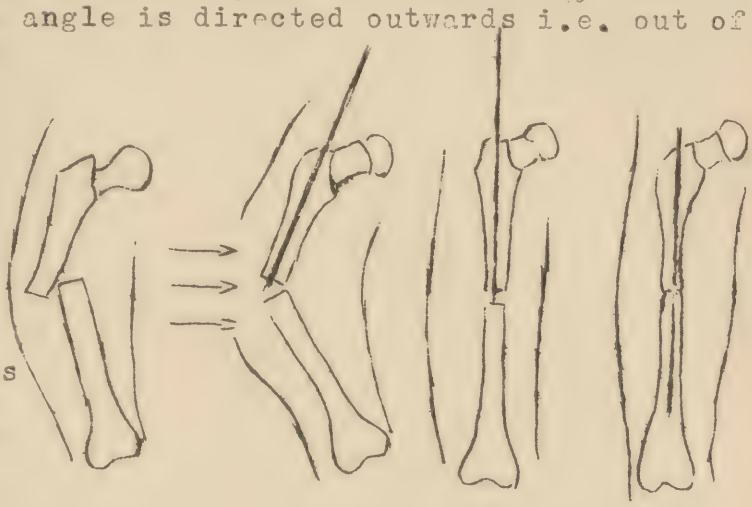
5. Resection of bone tumors.

The insertion of a nail into the marrow cavity is much easier with an osteotomy than with a percutaneous nailing. In this the marrow cavity is opened up and the insertion is made under the control of the eye. Often the marrow cavity may be open already. If not, this can easily be done with the awl, gouge or drill, because its closure is comparatively soft. With the leg, the forearm and the arm above the elbow the nail is inserted at spots distant from the fracture as in percutaneous nailing. The nail tip is visible in the depth of the wound in the marrow cavity of one of the bone shafts. It is then inserted into the marrow cavity of the other fracture, whereupon the nail can be driven home. By this the osteosynthesis is completed. At the thigh the side position may be recommended, the patient lying upon the sound leg. In general the skin incision will be on the outside which allows easy access to the bone without endangering larger vessels. In the opened marrow cavity of the proximal piece a guide rod is inserted and is pushed to the top of the trochanter where it easily and with a sudden movement penetrates the compacta which is very thin here. Its tip can be felt under the skin of the buttock. This tip



Ill. 80

is exposed by a short skin incision (Ill. 80). The nail is then slipped upon the guide rod and is driven in, until it extends out of the marrow cavity of the proximal fragment for ½ centimeter. Usually it is easily possible to put the bone fragments of the thigh together and to drive the nail into the distal marrow cavity. If, however, a shortening caused by an old, badly healed fracture has existed many years, especially with robust men it will not be possible to equalize the shortening even with the extension apparatus and with the strongest traction forces. In most cases the thighs stand in a bowed position. After severing the bones at the old fracture site it will not be difficult to put the fragments together so that they form an angle. The point of the angle is directed outwards i.e. out of the wound. An assistant presses this point inwards with great force, until the straight position of the osteotomy site is achieved (Ill. 81). The moment the angulation is overcome the nail must be driven in. It must never be done before this has been achieved in the hope that the nail would achieve the required straightening of the bone by penetrating into the distal marrow cavity. It cannot do that. The inevitable result would be the breaking out of large fragments of the cortex of the distal fragment. A further technical trick must be employed in those osteotomies which are located far proximally (at about the height of the trochanter minor). Here, it will be advisable not to sever the bone completely at once but only to open up the marrow cavity. A part of the medial wall is kept untouched temporarily. Then a small guide rod is inserted into the opened up marrow cavity and the nail is inserted in the way described. In the case of a complete severing of the bone at that place the proximal fragment is at once most strongly abducted and bent, because the corresponding muscle groups preponderate. By this the insertion of the nail becomes somewhat difficult because one hardly ever has sufficient power, even with the guide rod, to correct the position of the piece. The intervention will be rendered easier by inserting a second nail into the marrow cavity of the proximal fragment for a short time. Thus one has an excellent handle for the correction of the position until the nail has been inserted to the required depth. The periosteum must be handled as gently as possible. In general it is possible to get at the place of the fracture or of the intended osteotomy by pushing aside the muscles. It must be admitted, however, that by doing so the wound can be examined less easily than when the periosteum has been removed more extensively, and that by this the operation



Illustr. 81

is made somewhat more difficult. The severing of two fragments will, however, be possible in the case of a thigh fracture healed in a faulty position by the leverage of a very strong rasparatory placed between the fragments. Afterwards the fracture planes must only be smoothed a little so as to fit well one upon the other. Besides that the opening up of the marrow cavity, as described above must be made. The jagged edges and projections of the surplus callus and the callus bridge must not be touched, in order to avoid injuries to the periosteum and unnecessary damage to tissue. They are valuable building material near the bone fracture.

If the badly healed fracture is several years old it will be necessary to use a chisel and a saw. In this case too only the two planes fitting one upon the other will be prepared. This will be achieved in the easiest way with the circular saw which must be held with the two hands. The position of the severing planes depends on the position and the shape of the former fracture planes.

In the case of a transverse fracture the two saw planes must stand vertical to the axis of the bone shaft at the lower end of the upper fragment and at the upper end of the lower fragment so that after the insertion of the nails the ends fit together as well as possible. (Ill. 82). In the same way oblique saw planes are made with what were originally oblique fractures. The saw planes go through the intact periosteum at the site of the former fracture so that the callus caps formed at the fracture site are sawed into. They form a broad support at the point of contact which contributes to a speedy and secure healing. The planes must not be too high or too low in order to prevent the operated leg from becoming shorter or longer than the other one. It is to be observed that a part of the bone cortex is reabsorbed, so that a little defect remains after the osteosynthesis. These saw planes usually open up the marrow cavity. In any case it will be easy to do so from there.

After the saw planes have been made the severing of the two fragments is completed by strokes with the large chisel, exactly in the direction of the former corpacta borders between the fragments. In this way it will soon be possible to sever the two fragments by leverage. The nailing operation is done in the usual way (Ill. 83). Here also the surgeon must see to it that no lateral or medial rotation of the distal fragment is possible

An osteotomy advisable because of marked angulation at the old fracture site will be performed much more easily, as after the sawing off of the fracture ends only a correction of the axis will be necessary.

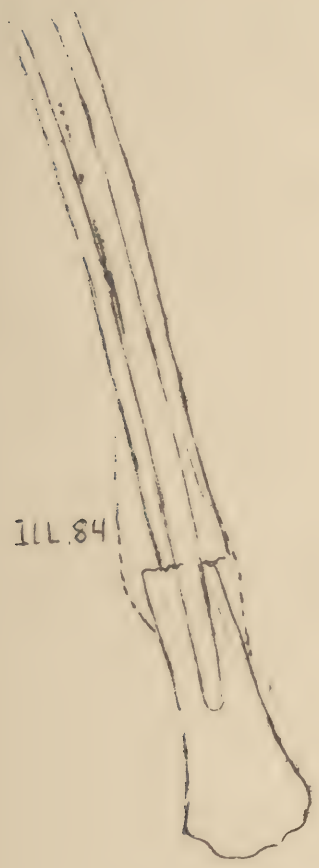
A rotation osteotomy which formerly was a rare occurrence will to-day, after the introduction of marrow nailing, however, be reuired the more frequently the larger the number of surgeons who perform nailing operations without devoting that care to the after treatment which is so urgently required. So it will happen again and again that a faulty rotary position is observed

Illustr. 83

only after it has become impossible to correct it during the "ether rausch".

The operation is not difficult to perform. First of all it must be ascertained by how many degress the leg has turned. In the case of a leg bent at a right angle and slightly bent hip both the hip joints are brought to a maximal inner rotation. The difference between the respective position of the leg is a sufficient indication for the number of degrees by which the rotation osteotomy must be made. In many cases it will be advisable not to perform the osteotomy at the old fracture site. It will be better to choose the place which proves to be most suitable for nailing, i.e. if possible in the middle of the bone. In addition to this a notching of the osteotomy spot must be made, in order to avoid further rotary displacements without using a plaster cast. First the nail must be loosened a little with some hammer strokes. After that the bone is severed except the bone bridge by the Gigli-saw (in case of an inserted nail), which must be left intact if the blades of the saw are guided in a parallel direction during the sawing process. After that two kerfs must be made in the bone bridge with the circular saw so that a tenon is left standing either on the upper or the lower fragment. The remaining small bone bridges are severed with a fine chisel.

For the bone tenon at the one fragment a corresponding hole must be made in the other one. To achieve this the nail should be withdrawn from the place of the osteotomy so that with a corresponding bending the bone end is kept well accessible for the circular saw. The only thing left to do then is the necessary turning of the fragments and the reinsertion of the nail (Ill. 84).



Ill. 84

Notching is safer than the selection of a new and thicker nail. For one thing the latter may jam in the callus of the fracture and in the second place this nail, even if it fits in well, may loosen a couple of days later, because the planes of the osteotomy are quite smooth and not notched.

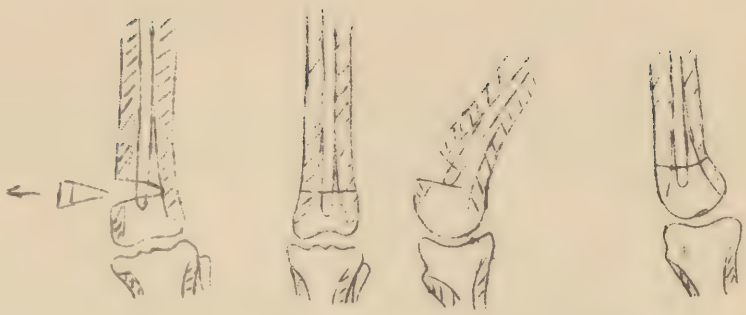
In the case of a congenital bending of the long bone shafts, not acquired by a bone fracture, the marrow nail operation can be applied only in comparatively few cases. It is the principle of the nailing operation itself to adjust the former shape of the bone - so to speak automatically. In the case of a late rachitic bowing of the leg the nail must follow the curvature in both fragments and must have a correspondingly strong bending at the fracture site, as is shown in Ill. 85. Such osteotomies are often apt to result in a delayed formation of callus, obviously due to the jamming effect of the nail. In such cases it cannot fulfuil its function to serve as a gliding splint, but mostly because under such conditions the leg nail must be mechanically insufficient and the fracture has become insufficiently fixed.

Bones with a proportionally small bending radius i. e. bones with bendings which are only of small extent as is often the case with rachitic bandy legs may be severed after the method of HELFRICH and a straight nail may be applied with good result.(KUENTSCHER). The rotary correction, often necessary in such cases may be achieved by the removal of a bone wedge.

Ill. 85

The nail is applied with excellent result in the case of a supracondylar osteotomy which must be made in the case of a knock-kneed leg or a knee contracture (GUENTZ). Of course a plaster cast is absolutely necessary but a shifting of the fragments will certainly not occur. The time required for the plaster cast may be shortened. The technique of the nailing corresponds here to the usual procedure. Nevertheless it must be pointed out once again that the bone ends should fit one upon the other as well as possible, so that their position should determine the axis of the bone. The nail prevents a lateral displacement, and the better the bone ends stand one upon the other the earlier it will

be possible to remove the plaster cast (Ill. 86).



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Illustr. 86

The lengthening of a bone for a couple of centimeters may be done even without the planned jamming of the nail. Two difficulties are to be overcome in this case, first the stretching of the soft parts, secondly, the possibility that the separated bone ends may approach each other again.

It is impossible to stretch the soft parts of the thigh for four or five centimeters during one setting i.e. within one hour. The technique of bending at the fracture site, described above in case of fracture shortened during the healing, cannot be applied, for, while in the latter case two strong bone ends are standing one upon the other, here two weak bone shafts are involved, which might become fractured again when the weight bearing is too strong. That is why the stretching of the soft parts must be done during the period of a couple of days. A nail which allows such a procedure is in preparation.

The extension osteotomy can be made with the means presently at our disposal.

First operation

1. Z-shaped osteotomy at the narrowest part of the marrow cavity.

2. Insertion of the nail after it was found suitable before the fluoroscopic screen.

3. Insertion of a V2A-guide rod from the osteotomy spot into the proximal fragment (without a cross handle, with a hole near the tip). Before the tip of the guide rod penetrates the skin above the trochanter, the skin must be pulled sideways to a great extent. In this way one makes it possible that during the second operation one may work a couple of centimeters distant from the first incision.

4. Insertion of the guid rod into the marrow cavity of the distal bone fragment.

5. Applying of a supracondylar wire extension.

Second operation

6. Nailing as soon as the necessary length of the bone has been attained. For the nailing the tip of the insertion guide rod must be exposed. Then the guide rod must be extracted with forceps far enough so that it is possible to insert a wire into its hole. The reduction must be done before the X-ray screen, and in such a way that on no account will the nail impinge on distal bone compacta. Any forcible reduction must be avoided in order to prevent a fracture of the bone ends.

7. Removal of the guide rod.

8. The wire extension may be removed or left with a little weight (load).

If a second operation is not possible for some reason or other the healing in extension must be waited for. The guide rod (made of V2-steel) will secure the right position of the fragments.

In most cases the indication will be given for a suture of a nerve, in fewer cases for a suture of an artery. One will decide on shortening a sound leg only if the normal length of the sound leg cannot be achieved in any way, or, if an exceptionally tall patient assents voluntarily and readily to the shortening. The incision should be made in an oblique direction (GUENTZ), in order to achieve favorable conditions for the healing (see general chapter).

As an example of a rather rare case of an indication the above illustration of a forearm may be shown (Ill. 87).

After the resection of a correspondingly long bone segment the osteotomy wound must be treated with the marrow nail as usual. In order to prevent a subsequent giving way of the bone ends (arm above the elbow and forearm) one must try to achieve an ideal nailing. This is comparatively easy, as in general the place for the osteotomy may be put at the spot most favorable for the nailing.

After the resection of bone tumors the nailing is to be done in much the same way as usual.

Illustr. 87

19. THE NAILING OF A SPONTANEOUS FRACTURE

Spontaneous fractures must be given special consideration in connection with the nailing operation. In most cases they are fractures of weak bones, enfeebled by tumor metastasis, in rare cases by osteoporosis or other factors. Curiously enough the tumor metastasis is to be found chiefly in the upper third of the thigh, i.e. at a favorable spot. In connection with the nailing it must be taken into consideration that in general the nail is meant to provide a sufficient stabilization for the rest of the patients life, because these fractures do not show a tendency (or only very little) to healing even after X-ray treatment. In the second place chiefly atrophic bones with a very thin compacta and correspondingly large marrow cavities are concerned so that customary sizes of nails can be used only seldom. In the third place the bone is comparatively soft, and in the fourth and last place the nail is exposed to little bending force, as the patients are usually elderly and frail persons.

The facts given above make it advisable to use a special nail.

As the nail need not be particularly proof against bending the sheet metal may be somewhat thinner and the elasticity of its

cross section can be all the greater. Its hat-shaped cross-section grants to it not only the required elasticity but has the further advantage that the nail touches the bone wall only with its three narrow longitudinal planes, its three edges. During the first few weeks the bone yields to the pressure of the nail. Because of its elasticity the nail formes grooves which permit it to attain its former shape and so become loose. These grooves are deep enough to prevent a lateral dispalcement of the fragments with certainty.

Even a patient who cannot hope for a bony healing of his fracture will be able to walk with his bones in splints without any additional protective casts.

For the rest, the technique of the nailing does not differ from the usual method (Ill. 88). In addition only the softness of the bones must be taken into consideration, especially when

inserting the nail into the distal fragment. The axis of this fragment must be put into the right position from outside and the adjustment must not be left to the penetrating nail, as may be done safely with solid bones.

With bone tumors tissue substances are frequently ejected with the marrow juice which renders possible a reliable tumor diagnosis, because they are suitable for a histological examination.

20. THE Y-NAIL

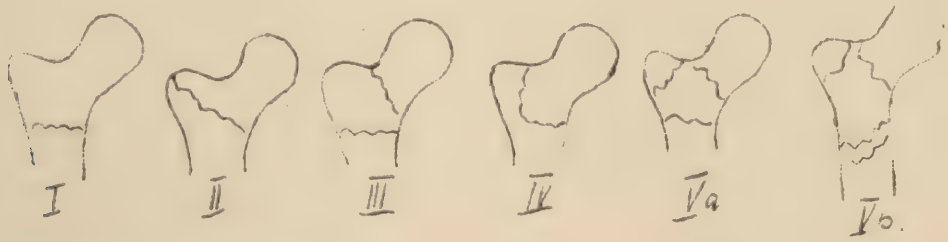
The pertrochanteric fracture demands a special treatment with the nail. It is a fracture which does not offer any difficulties with regard to reduction and fixation. Nevertheless it often causes a coxa vara position. It does, however, not show

a tendency to a delayed formation of callus or pseudarthrosis. Moreover in nailing the special advantage of the new method i.e. that the fracture site is left untouched, is neutralized in that case. As the fracture must be exposed, occasional infection of the operation wound will in most cases result in a suppuration of the fracture site. Nevertheless, the applying of the Y-shaped nail represents a great progress - it prevents a long confinement to bed and facilitates the nursing. The stability of the Y-shaped nail is so great in comparison with the nailing of the neck of the femur that the patient may get up a couple of days after the operation.

From what has been said before the indication is obvious. All those patients should be nailed who are endangered by a long confinement to bed, and the danger of an infection must be accepted. The advantages and disadvantages of this method must be explained to patients not belonging to this group, so that they may decide themselves whether the operation should be performed or not.

The method of inserting the nail depends on the shape of the fracture. It will be advisable to obtain an exact knowledge of the fracture lines before the operation. It must be admitted that in many cases this may not be easy. Frecuently it will be possible to get the necessary clearness only by X-ray pictures made before the operation in the extension of the fracture. The fragments wedged together before are then detached, and it is easier to make out the fracture lines.

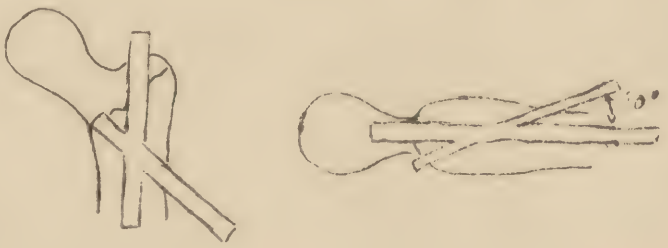
The fractures of the trochanter major and its immediate neighbourhood may be suitably divided into six groups for the nailing (A. W. FISCHER and MAATZ) (Ill. 89)



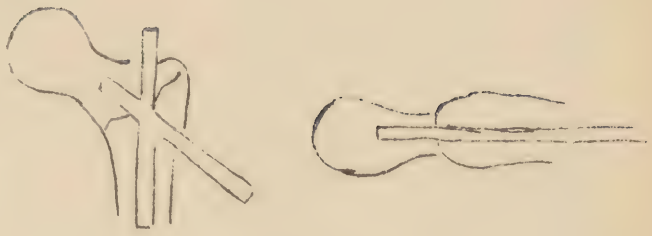
Group I, the subtrochanteric fracture is secured sufficiently by a conical nail.

The other groups should be treated with the Y-nail. The shapes of the fragments are very important for the indications and the technique of the operation.

The operation is very simple in its principal features. The marrow nail must be inserted into the femur to the supposed correct depth. The corticalis must be pierced 8 centimeters below the nail head end, and the transverse nail must be introduced a little into the slit of the marrow nail. The X-ray pictures to be taken then show the fracture reduction probably necessary and the correction of the height and rotation movement still required. (Ill. 90). This can be done very accurately, because the shifting of the marrow nail in an upward direction to the corticalis drill hole which must be widened to the corresponding side, is executed with the chisel or rongeur.



After that the marrow nail (with the transverse nail inserted) can be turned to the required angle in the marrow cavity. Further control X-ray pictures must then show that the transverse nail points to the middle of the neck of the femur in both its planes. This means that it must not be seen in the second plane, because it is covered completely by the marrow nail (Ill. 91).



Ill. 91

This technique requires a wide opening of the fracture site. For some patients the very large operation wound will cause a most injurious wound shock and it will, as is to be expected, be in great danger of becoming infected.

Therefore it was necessary to construct a special insertion apparatus which makes it possible to insert Y-nails percutaneously (MAATZ). After it has been tested sufficiently, the nailing of pertrochanteric fractures with it can be strongly recommended. Injurious effects on the wound were more rarely observed and the wound shock is not greater than with the other methods of marrow nailing. Nevertheless, a very strict indication is to be recommended, i. e. in the beginning only patients of group II should be nailed (to whom a long confinement to bed would prov dangerous). The number of persons which can be subjected to this operation will afterwards increase quickly.

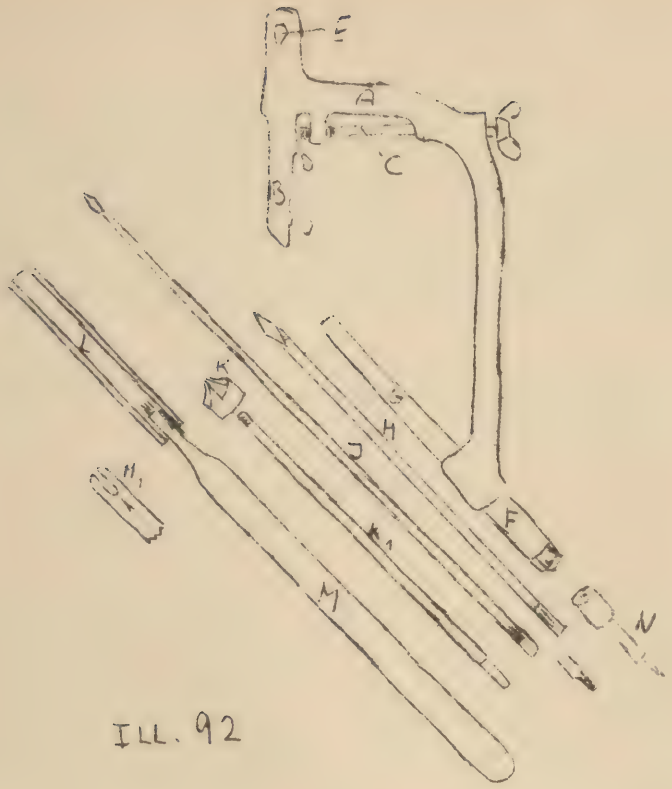
The principle of the insertion apparatus is very simple. It serves merely to introduce the transverse nail percutaneously into the slit of the marrow nail. It is easy to understand that the surgeon will at first feel somewhat uneasy on seeing the different drills and handles belonging to the insertion apparatus. They are, however, required and the surgeon will be fully compensated for all his trouble the moment the transverse nail disappears in the lateral slit in the skin, and makes its way safely through the slit in the marrow nail into the femur neck and head.

Description of the insertion apparatus (Ill. 92)

The clamp (A) must be put on the head of the marrow nail with the dovetail (B) in place. It is then fastened with the screw pin (C) which enters the hole of the nail. The nail and the screw must fit tightly. If, however, a single Y-nail is not sufficiently tight the cam (D) may be raised a little by any mechanism with a layer of metal and, if necessary, this may be removed again. Into the hole (E) a hook can be inserted and the nail extracted as required in each individual case.

The tube (G) fixed in the tube holder (F) by a screw serves as a guide for the drills and cutters.

The axis of the tube is 2,5 millimeters below the middle of the slit of the marrow nail.. This variation is allowed because the drill or cutter touching the corticalis obliquely is forced upwards for about 1,5 millimeter even when penetrating slowly, and a further millimeter is allowed for any further deviation (Ill. 93).

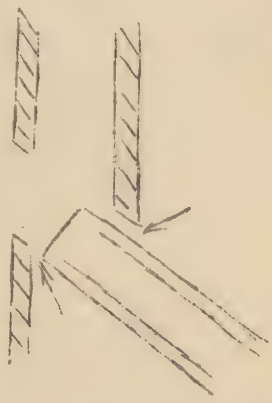


Ill. 92

A transverse nail touching the marrow nail too far distally will invariably wander upwards i.e. into the slit. A transverse nail inserted too far proximally will jam and force the marrow nail upwards, so that the previous result of the operation will be frustrated. As a further protective measure the transverse nail is round shaped at its upper leading edge. If, however, this nail should catch on the edge of the marrow nail its oblique part must be increased with a file.

It is necessary that the operating surgeon should know that the axis of the tubes is fixed in the above described way as he must ascertain it each time before inserting the nail whether the insertion apparatus is straight or not. Otherwise he may try to correct this intentional deviation in position.

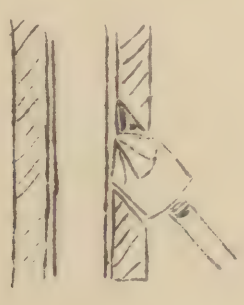
The tube (F) extends to the corticalis. Nevertheless the first hole must be made in the corticalis with a short thick cutter in order to prevent a slipping upwards. After that the rod with a cutting edge (J), which tapers towards the tip, is introduced. In order to get a better view of the control picture it is made so long that it can penetrate the head of the femur.



Ill. 93

The final drill hole in the corticalis is made with the large cutter (K) and it must be removed again when no longer needed, since the cutter holder must be introduced from outside owing to lack of space. The cutter is made of such length that damage cannot be caused by the nail and the cutter coming into contact.

A small bone edge is of necessity left standing for the time being at the upper edge of the bored hole, which must be penetrated by the transverse nail (Ill. 94). The transverse nail may be inserted easily and this bone edge is not of any disadvantage, since the nail is pressed downward by it, i. e. in a favorable direction. The surgeon must, however, know that during the insertion a certain resistance must be overcome. If it is very strong it will be better to extract the nail again. If a faulty contact with the upper end of the slit in the marrow nail occurs this may be observed by a deformation of the upper edge of the transverse nail. Any deformation must be removed accordingly.



Ill. 94

The transverse nail or nail for the neck of the femur (L) must be inserted into the slit of the elastic fork (M). It fits well into the tube holder (F) the tube of which has been removed, and in this way the proper guidance of the nail is achieved. It should be inserted with light hammer strokes. The nail must then extend out of the corticalis as far as the length of the notch in the nail holder (M).

All cutters are connected with the drill rod by an inserted piece (N) so that the connection with the shaft is possible by simply putting them on during the frequent changes.

After a sufficient knowledge of the apparatus the nailing is easy to describe:

1. The patient is put on the table in a supine position as usual for nailing the neck of the femur. The injured leg must be left free. It must be brought to a maximal flexion, abduction and inner rotation, in order to achieve the insertion of the guide rod and the marrow nail. If the patient is pushed towards the edge of the table as far as possible the guide rod can easily be inserted percutaneously into the marrow cavity obliquely from below . As soon as the nail has reached the marrow cavity the guide rod can be removed, because it is not required any more, or, rather, it must be removed because the head end of the marrow nail leaves no room for it. Before the disappearance of the nail head end under the skin the clamp is put on. The nail is then inserted in such a way that 2 centimeters of it stand out of the bone. It is very important that the nail should have the right position from the very first. One has to go by the position of the knee-cap which indicates the frontal plane of the leg. The plane of the clamp must be 30° posteriorly fro the frontal plane, because the neck of the femur points frontwards to the same degree. (Ill. 95)

2. The position of the patient is the same as with the femur neck nailing.

3. Final closure.

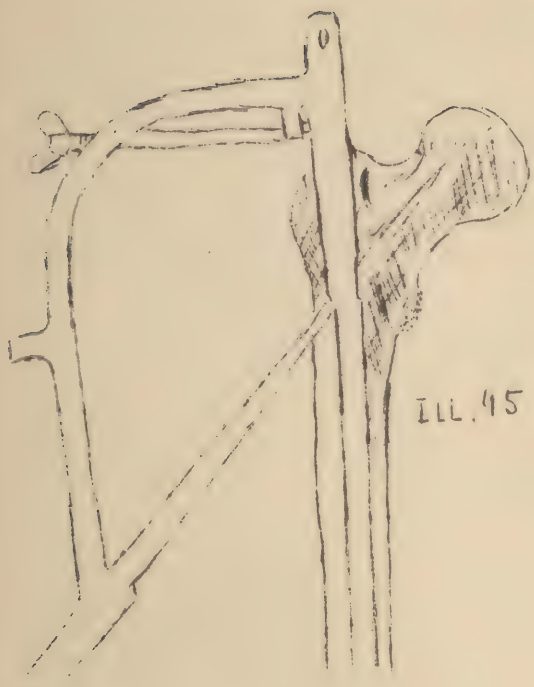
4. Fixing of the tube which indicates the direction of the incision. The tube can then be inserted.

5. The small corticalis drill hole is made with the short thick cutter (H). Push it in slowly in order to avoid too strong a deviation in the upward direction.

6. Insertion of the rod with cutter tip (J).

7. X-ray pictures in two planes for the control of the location of the fracture and the position of the sound with cutting tip. (Ill. 96) .

8. Make all the necessary corrections. First of all the rod with cutting tip must be removed, then the necessary correction of the fracture site must be made, then the correction of the height and rotation must be made accordingly. After that one can decide whether the tube must be removed or not and a new hole in the skin made, or, whether the elasticity of the soft parts makes the shifting of it possible. If corrections are necessary the following procedure is required:


Ill. 45


Ill. 46

9. A new opening is made with a gimlet and the rod with a cutter is inserted under X-ray control in two planes.

10. If the sound wire indicates that the direction of the tube leads through the middle of the neck of the femur and its head, the corticalis drill hole must be made with the large cutter.

11. Removal of the cutter and tube.

12. Insertion of the nail held in the nail carrier with light hammer strokes.

13. X-ray control.

14. Removal of the clamp and closing of the wound.

The short skin incisions may be closed with two stich sutures.

Objections raised at first against the use of the cutter without adequate protection of the surrounding soft parts were disproved by the experiences during the operations. Even the large cutter is quickly covered with soft particles torn from the surrounding soft parts, so that serious wound necrosis will not occur and practice has shown that the wounds will heal most satisfactorily.

If in the beginning the surgeon is not quite certain how far the marrow nail is to be driven in and in which position the use of the sound (just as with the nailing of the neck of the femur) will be helpful. This must be inserted at the supposedly right place in the supposedly right direction. By X-ray control the necessary corrections are indicated which must be made during the later insertion of the marrow nail. The position of the clamp must be in accordance with the position of the sound .

It will not be difficult to nail groups I, II and IV with the technique described above. Greater difficulties are to be encountered with groups III, Va and Vb especially concerning the reduction if the axis of the neck of the femur cannot be directed towards the middle of the marrow cavity. But this fracture too cannot be nailed without reduction.

Besides this is must be considered that a normal nail must be insufficient. These nails are short and conically shaped. They provide insufficient protection against rotation as the friction between the marrow nail and the bone is not strong enough. This means that fractures of the groups III, Va and Vb are not protected against rotation for the far end of the transverse nail is situated either in the fracture slit, so that it does not find a sufficient hold to prevent a rotation, or the second fracture line lies even farther distally.

In such cases therefore marrow nails must be used which are made to measure (up to a thickness of 18 millimeters) and which secure sufficient friction between the nail and the bone.

It stands to reason that the insertion will be somewhat difficult due to displacement of the fracture by stroks with a hammer, especially if corrections are to be made, and moreover, there is the difficulty of achieving better position of the nail, since the nail can be turned only after it has been almost entirely removed. Therefore, the greatest care must be taken in these cases that the nail gets its right position in the distal fragment at first. At the same time the position of the knee cap must be considered. Slight rotation faults can then be corrected by turning the nail with the distal fragment.

Patients treated with the Y-nail may get up as soon as their general condition and the wound pain makes it possible. The fragments are well stabilized.

The nail can be removed after the lapse of three to four months. For this purpose only slight skin incisions are required. The patient lies on the sound side. When removing the nail of the neck of the femur the leg must be rotated inwards by about 30 degrees if the operation starts at the old wound.

This large nail too may safely be left in the bone, especially if the patients are elderly who do not want to undergo another operation. Patients who were operated on three years ago have so far not suffered any injurious effect caused by this large metallic foreign body.

21. THE SUPRACONDYLAR T-FRACTURE

As a reduction and fixation of this most complicated kind of fracture is frequently not possible without an operation, and as any exposure is dangerous to the knee joint and the leg, it seemed to be advisable to utilize the advantages of marrow nailing with these fractures. The nail alone, however, will not suffice, since it is sure to push aside the condyles and to penetrate into the knee joint, i.e. by itself it always will aggravate the situation.

The shattered condyles must be connected with each other by a transverse wire and the tip of the marrow nail must be united with this transverse nail, to prevent a slipping back of the short fragment. It would be of very great advantage if the transverse nail could be inserted into a hole in the nail tip, directing the drill according to the X-ray indications. Circumstances, however, make it impossible for the time being to obtain that apparatus which is indeed not difficult to construct. So at present we must try to get along with the following method.

1. Insertion of a transverse wire and attaching of a Beck tension clamp. The wire should be rather near to the fracture site, in order to diminish the danger that the marrow nail may miss it.

2. Insertion of a marrow nail, which must have a wedge-shaped notch at its tip, is done in the usual way. Its exact length should be ascertained with special care.

3. In general the reduction of the fracture is possible only by using strong forces. The estension wire with clamp which lies in the lower fragment, and a traction strap on the upper fragment serve as handles. The required amount of traction, must be carefully judged, for putting the nail upon the transverse wire can be furnished only by a block-and-tackle.

The operation is rendered more difficult by the fact that one cannot obtain an unobstructed view (the tension clamp obstructs the view). Nevertheless it is worth while trying it.

During the first six to seven weeks it will be advisable according to the position of the fracture and the formation of callus - to apply a slight additional extension to the leg (Tuberositas tibiae or Calcaneus), for it must be borne in mind that a compound fracture is concerned, and that the muscular forces acting upon the fragments (Muscles of the leg and the thigh) are very great. The leg must be put on a Braun splint. After the removal of the nail and the transverse wire a plaster cast must be applied to prevent new displacement of the fragments.

In the beginning special attention must be paid to the insertion site of the transverse nail. As the final position of the stretched wire is different from the one during the insertion, corresponding relieving incisions are recommended, in order to prevent the wire from cutting through the skin and perhaps causing an infection.

22. ATYPICAL NAILINGS

Atypical nailing may be necessary if the broken bone shows pathological curvatures or if a neighbouring joint shows a stiffening or a contraction. There are many possibilities, some of which may be mentioned here:

1. Transverse fracture of the leg immediately below the knee-joint which is stiffened at 135°. The straight nail was inserted into the tibia from the middle of the femur passing through the knee-joint. A correction of the curvature of the axis to 160° was achieved. The patient, a woman, was able to walk three weeks later without any inconvenience (Ill. 97)

2. A sixteen-year old patient with a stiff strongly recurved knee-joint was subjected to osteotomy. It was performed immediately above the knee-joint and stabilized in the thigh bone with a marrow nail 60 centimeters long, inserted percutaneously at the trochanter, and extending to the middle of the tibia. The patient was able to get up with a straight leg a fortnight later.

Illustr. 97

3. A subtrochanteric fracture combined with a stiff hip-joint can be nailed in the usual way. As regards the position of the leg it must be taken into consideration that in this case the distal fragment must correspond to the position of the proximal fragment, i.e. the leg must be extended in the corresponding position. As regards the after-treatment it must be taken into consideration that the forces which have the tendency to displace the fragments are unusually strong, since the hip-joint cannot give way. Therefore a confinement to bed for at least 4-5 weeks will be necessary. During the first few weeks a comfortable position of the patient must be achieved and renewed traumas must be prevented, since the leg is a large lever which has the power to bend the nail or even cause a piercing of the trochanter by the nail.

4. A pseudarthrosis of the arm above the elbow combined with a stiffened elbow joint can be treated with a straight thigh nail (here 10 millimeter), as it may pass through the joint. In this way the disadvantage of the long arm of the lever is neutralized which renders healing so difficult in such cases.

5. Oblique fracture of the leg at the border between the middle and the lower third in the case of a very narrow cavity (diameter 6 millimeters). As the turn spread nail is insufficient and as a nail with inclined plane (diameter 6 millimeters) may break easily, a conical nail can be inserted from the inner aspect of the bone. Thus the nail has a diameter of 9 millimeters at the fracture site (Ill. 98).

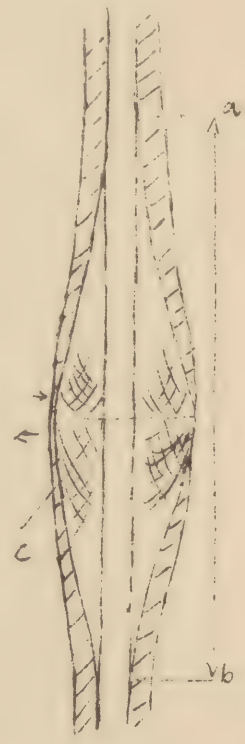
6. Another possibility to apply the narrow nail is to be found in the transplantation of bones. In the case shown here the proximal end of the ulna was resected because of a relapse of osteitis fibrosa. Two months later the projecting end of the radius

Ill 98

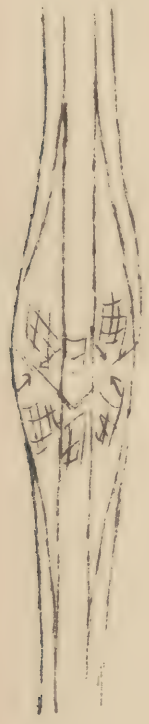
was divided and the middle piece having become detached in this way was transplanted upon the end of the ulna. The bones were stabilized with marrow nails.

Three weeks later the radius osteotomy wound was well healed and the transplanted part was well covered with callus. Nothing can be said yet about the further development.

7. An artificial ankylosis was first tried three times with a long nail. One of the patients, a tabetic, though summoned several times did not show up for the after-treatment. Owing to the peculiarity of the disease his statement that he had no trouble at all is not to be regarded as positive proof of a bony healing. The second patient, a woman died one year after the operation, before the after-treatment had started, while the third patient did not show any bony healing. The nail which is 60 centimeters long and must be inserted percutaneously at the trochanter has indeed a great stability, which however, is probably not sufficient to neutralize all forces tending to cause a lateral displacement at the bone ends, since the places at the bones of the leg and the thigh which hold the nail firmly are 25 centimeters apart. Along that stretch the stabilization of the extremity depends entirely on the stability of the nail. Every movement in the nail and every bending motion of the nail must result in a bending movement at the bone ends, in most cases it must even lead to a lateral displacement as each tipping over would cause a lengthening of the extremity. All the muscles, and the weight of the body, however, constantly counteract this lengthening so that there is no other possibility than for the fragments to evade this by a movement resulting in a lateral displacement. These movements will be the stronger the more distant the points a and b are from each other (Ill. 99). Therefore the proper thing is to make a V-shaped resection. The bone ends will then be firmly pressed together just as with an oblique fracture, and any movements leading to a lateral displacement will be impossible. (Ill. 100)



Ill. 99



8. If a bone has a second fracture and in the case of a refracture we have to deal with a special kind of nailing operation, In that case it must be borne in mind that after the removal of the nail near the old fracture site the marrow cavity has become rather narrow by the formation of narrow callus. Unfortunately we have therfore to choose a thinner nail than in the first nailing. Otherwise the nail would get stuck at the old fracture site . It will be more advisable to fit the nail tip with a few jagged teeth so that it may create for itself a new bed in the callus.

Ill. 101

9. In a single case, at the request of a patient, we prophylactically stabilized a thigh bone with the marrow nail in the presence of a subtrochanteric metastasis from a breast carcenoma (Ill. 101). Three months later the metastasis could not be observed any more, so that we could remove the nail again.

10. The subtrochanteric osteotomy is performed most successful with a strongly curved thigh nail.

By the elastic transformation in its longitudinal profile the nail is fixed firmly, so that an additional plaster cast is not required.

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